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UsaGame – A New Methodology to Support User-Centered Design of Touchscreen Game Applications

Dissertação para Obtenção do Grau de Mestre em Engenharia e Gestão Industrial

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ABSTRACT

Touchscreen mobile devices growth resulted in an explosion of the mobile applications. Focusing on touch mobile game applications this study aims to fulfill a research gap, creating appropriate usability guidelines for these applications. Concerns about usability, touch technologies, mobile devices and game testing, provided the background needs for this study. Initial game application tests allowed for the creation and implementation of such proposed usability guidelines into a support checklist (UsaGame), designed to help applications developers. An evaluation test was performed with 20 users in order to assess the validity of the proposed guidelines. Results from the test of the two builds from the same game application allowed comparisons that led to the assessment of the importance of some of the guidelines implemented into the application. Results suggested a usability improvement on the game application implemented with the guidelines. Furthermore results allowed commenting on all proposed usability guidelines.

Keywords: Usability Touch guidelines, Mobile applications, Usability Checklist, Touch Mobile Devices.

RESUMO

O crescimento de dispositivos tácteis móveis despoletou um aumento no número de aplicações. No que diz respeito às aplicações de jogos para dispositivos tácteis móveis, este estudo tenta preencher uma lacuna na usabilidade dos jogos, criando para tal, recomendações de usabilidade apropriadas a jogos para dispositivos tácteis móveis. Fazem parte integrante deste estudo preocupações acerca de usabilidade, tecnologia táctil, dispositivos móveis e testes de jogos. Foram realizados testes iniciais a aplicações de jogos que permitiram criar e implementar recomendações de usabilidade numa *checklist* de apoio (UsaGame), desenhada para ajudar criadores de aplicações. Por fim, foi efetuado um teste de usabilidade a duas versões de um jogo (Megaramp), que contou com 20 participantes, com o objectivo de testar essas recomendações de usabilidade. A segunda versão do jogo foi desenvolvida com o apoio da checklist UsaGame, onde algumas das recomendações de usabilidade foram implementadas nessa versão. Os resultados desse teste permitiram fazer comparações entre as versões e determinar a importância de algumas recomendações que foram implementadas na versão final do jogo. Os resultados sugerem uma melhoria na usabilidade do jogo que foi desenvolvido com o apoio da *checklist* UsaGame. Outros resultados permitiram também tecer comentários sobre as restantes recomendações propostas.

Palavras-chave: Recomendações de Usabilidade para *touchscreens*, Aplicações móveis, *Checklist* de Usabilidade, Dispositivos tácteis móveis.

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ABBREVIATIONS

BST – Billabong Surf Trip

CW – Cognitive Walkthrough

CWP – Cognitive Walkthrough Protocol

CWU – Cognitive Walkthrough with Users

GD – Graceful Degradation

HE – Heuristic Evaluation

ITO – Indium Tin Oxide

PE – Progressive Enhancement

SAW – Surface Acoustic Waves

UCD – User-centered Design

UI – User Interface

UsaGame – Usability Evaluation Support Checklist for Touchscreen Mobile Game Applications

UX – User Experience

UXD – User-experience Design

CHAPTER 1 - INTRODUCTION

In this chapter it will be made a brief presentation of the contents of this study, consisting of: framework, objectives proposed and the structure of the thesis.

1.1 Framework

Computer usability guidelines have been extensively studied and developed by usability experts. However with the emergence of new technologies, such as, touchscreen mobile devices, new usability guidelines are required for a better user experience (UX). This Study is inserted among touchscreen mobile game applications usability, regarding usability and ergonomics concerns about their use and aiming to develop usability guidelines for touchscreen mobile devices.
Considering touchscreen history, it is now revolutionizing the cell phone industry. The adaptation of touchscreens for smaller dimensions may foster some usability concerns. Mobile technology advances and unique features, such as, slow or unreliable connectivity, small screen size, processing speed, limited power or sometimes inappropriate data entry methods, impose certain difficulties upon usability evaluation. Traditional guidelines and usability test methods used in desktop applications might not be directly applicable. Consequently it is essential to create or adopt existing usability guidelines and usability evaluation methods, to appropriately evaluate the usability of mobile applications (Zhang & Adipat, 2005).

The purpose of this study is a result from a gap identified in the research of touchscreen mobile device applications, more specifically regarding game applications. In this matter previous studies regarding touchscreens and their different types have been made (e.g., Broz et. al., 2012; Sjöberg, 2005). Nevertheless they lack on usability concerns, for this matter other studies must be considered for a more usability focused research regarding touch interfaces (e.g., Parikh & Esposito, 2012; Saffer, 2009). In a more intrinsic usability field comes usability touch problems, such as, key usability concerns in touch devices. Previous studies have been made focusing on key sizes and usability problems with touchscreen use (e.g., Colle & Hiszem, 2004; Findlater, Wobbrock, & Wigdor, 2011; Huang et. al., 2007; Park & Han, 2010). Moving into mobile devices research some studies can be highlighted that stand out usability concerns in a mobile device environment, where unreliable and unpredictable conditions occur that pose some challenges to an usability UX (Heo et. al. , 2009; Seward, 2011a). Within mobile devices and in the interest of this study come mobile applications research to assess the best practices in their use and development (e.g., Kaikkonen et. al., 2005; Zhang & Adipat, 2005). More recently (Nielsen & Budiu, 2013) focus on usability of mobile devices, mainly in smartphones and touch phones, and covers development and design topics for those mobile devices.

Regarding mobile game applications' specific field some previous studies can be held into account. Based in (Inostroza et.al., 2012) some mobile touch usability heuristics can be held into account for a more complete heuristic research. Previous studies regarding usability checklist have been made, nevertheless their focus deviates from the focus of this study. Ji, Park, & Yun,(2006) have made a usability checklist for mobile phones, however the focus of the study is not up to date. Their study does not include Smartphone use and their mobile applications, nevertheless their checklist serve as the bases for this study literature review. Furthermore (Tiresias, 2009) created a checklist for touchscreen that even though it might not be scientifically built it can provide viable guidelines for this study checklist development.

1.2 Objectives

This study aims to provide a tool to support the development of usability touch game applications.
For that it will be adapted previous guidelines and created new ones for touchscreen mobile game applications. More specifically the objective of this study is to create a checklist (UsaGame) to support the usability evaluation process of touchscreen mobile game applications that would help designers and developers throughout its development process. Along with the creation of the UsaGame checklist there were built some guidelines for better acknowledge of the checklist parameters.

The guidelines resultant from this study as well as the UsaGame checklist will be tested and analyzed through a usability evaluation test using a Cognitive Walkthrough Protocol (CWP). This test will have 20 participants and the objective is to assess the usability of a touchscreen mobile application (Megaramp) through two different game stages' tests.
Throughout this study a joint venture with a game development company allowed for a continuous analysis and monitoring of a development process of the Megaramp application. This will allow for the author to instill some usability guidelines into the specified application. The tests will provide usability metrics, such as, task success, time-on-task, and user satisfaction. The out coming results from these tests will be analyzed as well as some of the usability guidelines that where implement into the Megaramp game application. Improvement reports and furthermore usability metrics analysis will be performed to determine the effectiveness of those guidelines.

1.3 Structure

This thesis is divided into six main chapters:

- **Chapter 1 -** This first chapter includes an introduction of the thesis explaining its framework and objectives.

- **Chapter 2 -** This chapter has all the contents of the literature review necessary for this study. Throughout this chapter one can get acquaintance with the most important subjects for this study, being those Usability, Touchscreen technology and Mobile Touchscreen devices. This chapter will allow the author to have a full background sense of previous done studies and contents that provided the knowledge necessary for this study completion.
- **Chapter 3 -** In here the methodology of this study is explained, which explains the basic steps of this study development as well as its outputs as one can see in Figure 3.1. This thesis methodology contains another methodology within that explains the steps for the UsaGame development (see Figure 3.2).
- **Chapter 4 -** Highlights the major outputs of this study, the usability touchscreen game applications proposed guidelines and the UsaGame checklist creation. It is also explained in this chapter the usability evaluation test that will be performed to evaluate those guidelines.
- **Chapter 5 -** In this chapter it will be presented the results of the usability evaluation test done with 20 representative users of the mobile game application Megaramp. This chapter will also include the discussion of the results obtained.
- **Chapter 6 –** This chapter will figure the conclusions of this study, regarding the comparison of the results and proposed objectives of this study. Also in chapter six are addressed the limitations of this study in the pursuit of further research necessary.
- **References -** In part it will be presented all the references of the bibliography used in this study.
- **Annexes –** This last part contains the two relevant annexes for this study: UsaGame checklist (Annex 1) and the Cognitive Walkthrough Protocol (Annex 2).

CHAPTER 2 - LITERATURE REVIEW

Throughout this chapter the study main topics, such as, Usability, Mobile devices, Touchscreen technology and Game development will be addressed as well as the explanation of the literature necessary for this study development.

2.1 Usability

Products nowadays are becoming more and more complex and more indispensable and useful. With the spread and growth of technology, user requirements increase and usability comes even more important. Usability is not just a concept, is becoming indisputable one of the influencing strategy points for success on commercial products. Usability issues have already received attention from those in charge of accomplishing easy-to-use products. This can be assured in so many ways, for instance, consider the fact that it can determine whether a product succeeds or not. There is also a pointed increase in the number of employed professionals by the industry in this area of expertise, only to assure products are made surely to be easy-of-use.

Other than commercial issues, lack of usability could represent safety issues. Not only users can become annoyed by products with low usability but also put their lives at a risk. For instance lack of usability in a defibrillator could leave paramedics to waste precious time.

Usability is one of the main pillars of this study since it will provide appropriate knowledge for the construction of Touchscreen adequate guidelines and furthermore the creation of the checklist.

2.1.1 Concept and Definition

One can underline two influent authors when referring to usability, mostly because each one has many different publications on this matter. First Jakob Nielsen, a “usability” designer, consider by many as a pillar in usability, is widely known as one of the leading experts on making online content and technology easy to use (Pack, 2001). Second Patrick W. Jordan, marketing, design and brand strategist with successful publications some regarding usability concerns. Patrick W.Jordan is also considered to be one of the most influential practitioners in the usability field.

Many definitions of usability can be given but it can be seen in practical terms as the “user-friendliness” of products. It has been identified as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use” (ISO9241, 1998).

Usability derives from acceptability, which can be described as whether a system is good enough to accomplish all users’ requirements. For the time being machines do not need to be friendly but instead make life easier and do not stand in the way of those who use them. One can breakdown acceptability into social and practical attributes. Being the practical attribute the one that will give origin to usefulness and further usability. As shown in Figure 2.1 we have a breakdown model of acceptability (Nielsen, 1993).

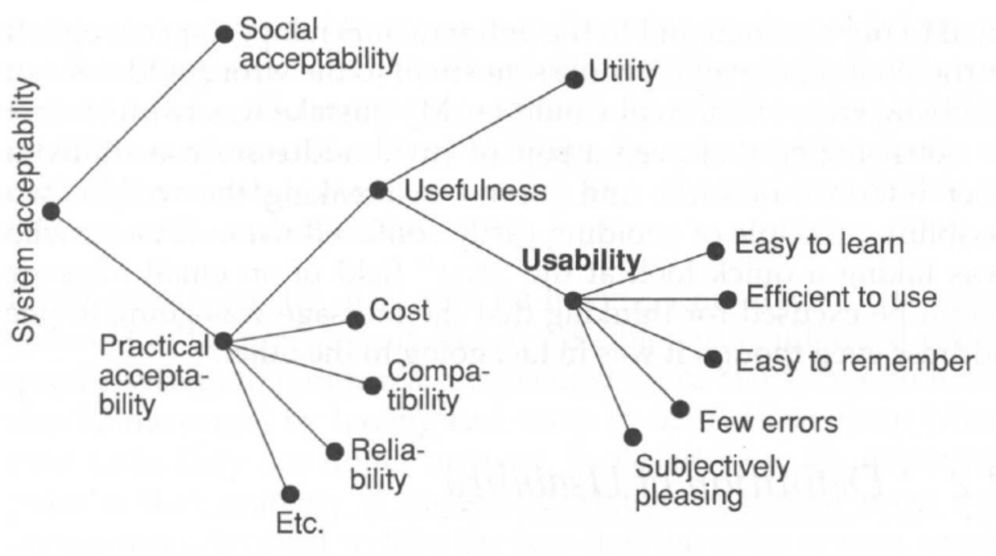

Figure 2.1 - A model of the attributes of system acceptability
Retrieved from:(Nielsen, 1993)

The usefulness of a system can be held as the issue of whether a system can be used to achieve desired goals. Utility is the definition of whether a system can do what is supposes to do, for instance considering a mobile phone that is intended to make phone calls; if it does not make them it does not have utility. Utility is not restricted only to hard work, for example educational software can have high utility if users actually learn from it. Usability in other hand is the issue of how users can perform tasks, in case of the mobile phone one can discuss phone calls usability, are they easy to perform, too many contacts and no search bar, too time consuming, questions like these can help usability measuring. Usability should be present in many system aspects that humans can interact, whether speaking of installation or maintenance features.

2.1.2 Principles of Usability for Design

According to Jakob Nielsen (Nielsen, 1993) usability has multiple components and can be associated with five attributes:

Learnability: How easy is for users to learn the system and complete tasks within the first time they use the system;

Efficiency*:* How fast do users complete the tasks, once they have learned the system;

Memorability: When users interact with the system after a period of not using it, how easy is for them to remember it;

Effectiveness*:* When using the system users should make few errors, and if they eventually occur it should be easy to recover from them. Serious errors must not occur;

Satisfaction: The system should be appellative and satisfying to use, therefore have a low complaint frequency rate.

Learnability

Systems need to be easy to learn, for that reason the first step when operating a new system is to learn how to use it. In a way this is the most fundamental usability attribute. Some systems can afford the fact that users need to be trained to overcome a hard-to-learn experience. Nevertheless generally all systems need to be easy to learn. Almost all UI (User Interface) have learning curves that start from zero where the user has zero efficiency. There are some exceptions, consider museum information display systems which intention is to be used once and as a result need to be as easy of use possible so the learning time can become approximately zero. It probably comes as one of the easier attributes to measure, the initial ease of learning. One can measure the initial learning of a user with time improvement charts to determine a learnability curve. One should be acquainted that not all users take the desired time to fully learn an interface before operating it, while performing a learnability analysis.

Efficiency of use

This attribute depends on UX and it is a learning process. For instance, some systems are so complex that take several years for users to achieve expert level performance. User's performance is a continuous process therefore its measurement is continuous, (e.g., number of seconds to complete a task). Consider for example if a user's performance has not increased for a period of time, then the user is likely to achieve a steady-state level of performance.

Upon analyzing this attribute one most come acquainted with the two most influence users, novice and expert users. Mainly their difference is the amount of time spent using the system. Where experts have a long period of hours spent operating the system, novice users are the ones that have made recent contact with the system and are still learning.

Memorability

There is a third category of users, known as Casual users. This category defines users as people who intermittently use a system. Instead of novice users, casual users have already operated the system before. For this reason they need to remember how to operate the system instead of learning the process all over again. To have an easy learning application is very important, especially for users who use the application sporadically. Memorability is by some means related to other attribute, Learnability. The easier it is to interact with an interface the more likely it is for users to remember how to use it. Interface memorability is rarely tested instead of other attributes, however there are two means of measuring it. First is to perform a test with casual users and measure the time needed to perform typical test tasks. Alternatively one could make a memory test to users. After making a test session with the system they would be asked to explain certain tasks, quote names of commands and their use.

Effectiveness

When operating systems, users are likely to make errors, the problem somehow is to minimize or eliminate those occurrences. Error rates are determined by the number of undesired actions while performing specified tasks. Errors have different impacts on effectiveness, some errors are emended by the users right upon they occur and therefore they only slow down users performance. These types of errors do not need to be counted separately because they are within the efficiency of use, where they take part in user's task completion time.

Other errors may have different consequences, such as, affect users work, making error recovery thorny. These last errors should be counted separately from minor errors and their frequency should be minimized.

Satisfaction

Interfaces need to be pleasant to use, so users can become satisfied whilst using them. Satisfaction can become an important attribute for systems that are used for nonworking purposes, such as, games, home computing and others. In these environments users are more likely to choose applications that are more pleasant to use than others. In work environments this may not be possible, since applications are sometimes previously chosen. To measure this attribute there are different methods to choose from. One can choose psycho physiological measures, such as, pupil dilatation, heart rate, blood pressure; nevertheless these measures imply certain experimental conditions that would disturb the relaxed atmosphere desired for users.

Subjective opinions come as the best predictors for user's likelihood towards the game application (Tullis & Albert, 2008). Examples of these subjective indicators can be any signs of unrest or impatience showed through the users whilst performing any interaction with the UI.

Jordan, (1998) gives a more wide description of usability attributes that one must consider in order to fully understand the concept of usability. According to Jordan, (1998) there are 10 principles for usable design. Even though some might come as equal to the ones described by Nielsen, (1993), there are a few attributes that are furthermore explanatory and give a more wide perspective of the usability concept.

1. ***Consistency***

Implementing consistency during products development allows users to perform similar tasks in similar ways even if different products are operated. In the context of website usability one can outstand a common feature: putting a text into bold or into italic are similar tasks, meaning that they should be operated through the same menu otherwise the user who had learnt how to format text into bold would select the wrong menu when invoking the italic command. If these features are not well implemented in some cases it may cause inconsistency, which generally leads users to make errors.

Consistency in basic functions is very important, for example considering cars, the foot pedals (for manual transmission) are generally displaced for this order, clutch on the left, brake in the center and accelerator on the right. This consistency means that a user can drive different cars once he has learned how to drive.

2. Compatibility

Designing products implementing compatibility ensures that the user's expectations of how the product works are among their knowledge.

It is a similar concept to consistency with the difference that compatibility refers to design regularities between a product and other outside sources, such as other type of products or other brand products, while consistency tends to refer design regularities among a group of specific products. Consider a simple example such as the print button, in word processing programs is usually fitted within the file menu. If the user is using another program, such as drawing or statistical software, he is likely to search for the file menu to achieve the print function. In this case program designs' would be compatible with user's expectations. Population stereotypes are another compatibility issues. These stereotypes are mainly assumptions made by people from a particular culture. Consider safety concerns, in nearly all cultures the color red is often associated to danger or emergency. Correspondingly the color green is related to the permission to proceed (can be seen in traffic lights).

3. Consideration of User Resources

It is important to keep in mind user resources implications, especially when overloaded. A system should not overcharge user resources. Computer typing programs require too much visual focus, whether for the keyboard or the screen, so other channels must be used.

An example of these issues happens whenever a new email is received and generally it is followed by a "beep". This allows users to better profit from their time, perform other tasks and be aware when the "beep" sounds that something has happened. This is an example of how to focus attention on audio channel when the visual channel may be highly loaded due to others tasks.

4. Feedback

UI Interaction is very important and in order for this to work properly interfaces must provide proper feedback of user's actions and their consequences. An example where the lack of feedback can be noticed is when sound feedback ("beep" sound) is not provided when dealing with in-car stereo. This can lead users to spend more time with actions and pressing buttons, which could lead users to deviate their attention from the road in order to check if the button they pressed was indeed the correct one. This example refers to feedback providing acknowledgement that a certain action has been taken. It is also relevant to provide feedback for the results of an action. Telephones provide a good example of this type of feedback. When a number is dialed it is then followed by a "beep" sound showing the user if the call is being made or if for the phone dialed is in use.

The feedback given from interface must be meaningful otherwise it could upset users and be meaningless.

5. Error Prevention and Recovery

Humans are very likely to commit errors, and it is bound to happen that during UI interactions those errors will eventually take place. To minimize these errors products can be designed to reduce the probability for them to occur and if they occur that the user can easily recover from them.

An example of design for quick error recovery is built into the spelling correction in word typing programs. When the user is typing and for mistake types words incorrectly, the program rapidly underlines the word in red so the user can easily acknowledge his mistake and even has the opportunity to recover from the error by clicking with the right mouse button and selecting the correct word.

Another good example of how a design can make error recovery easy is the “undo” feature provided in many computer based programs.

6. User Control

Product Designers should give users freedom to control their interactions with the product. Giving the user permission to customize products give them more usability and therefore results in better user satisfaction. There are some types of interfaces that often remove control from users. Consider interface application with timed-out menus. Some televisions have this type of menus that can cause problems to the user. If the user is trying to customize the television whilst consulting the manual, timed-out menus may not come as an advantage, because if the user does not make any input for a certain amount of time the menu could close up. A solution for this would be a feature that would allow users to set time-out time according to their needs.

When designing determined products adjustability must be a present concept, has it will allow different users to operate the same products. A good example of this is seen in some chair designs, that can ensure intended user dimension but at the same time allowing an easily configuration of either the height or angle of the backrest assuring that many users can use the same product.

7. Visual Clarity

The information displayed has to be quickly read without causing any confusion. Issues like, characters size, how much information in which place, which colors to use, among others, should be involved in product designing. On-screen interface designers must have in mind the distance that the interface will be used has it will affect the font size, contrast as well as the amount of information displayed. Also the issues of information placement are very important as well as visual clarity and contrast of the information. Consider for example TV monitors, with potential to use a lot of color, this feature is very helpful to distinguish modes. For instance sound parameters could be displayed in green whereas picture options could be displayed in yellow.

Too much information at one time can become a disadvantage; users would have to make an extra effort to find what they are looking for. For example consider TV screens, those involved in the design of the TV monitor must decide whether the whole screen is going to be used or just a small part, to display information wisely. Using the whole screen is better to acknowledge all information and allows bigger characters to be used, nevertheless it has a major drawback. The more screen is filled the more of the TV picture will be covered. Regarding menu information visual contrast is important to consider whether an opaque or slightly transparent background should be applied or not.

8. Prioritization of Functionality and Information

Products nowadays accomplish a vast range or features and for them to become useful is advised to prioritize some features. Normally most used features are given more importance and therefore have priority. When dealing with graphical interfaces on computer-based applications these issues may arise. These types of applications contain a wide range of features which can result on time-consuming feature search. The solution for these issues is the use of toolbars and icons that can be easily acknowledge and accessed. Also fitted along with menu-based systems are hierarchical structures that permit most frequently used functions to be immediately visible.

9. Appropriate Transfer of Technology

Adapt technologies made for a special purpose into other areas could enhance the usability of such technology as long as they are well adapted. Consider TV remote controls. Initially developed to be used by disabled people with difficulties to reach the TV monitor, and with the TV remote they could perform basic features, such as, change volume or channels. As it was becoming very useful some companies adopted them as a default accessory for every TV and it was meant to be used by all users. Indeed it has more features than the control panel built in the TV. Despite some less good design in remote controls it is still a good example of an appropriate transfer or technology that was first meant for a particular group of persons and then adapted for all users.

There are however examples with less benefits. For example the use of head-up displays (HUDs) in car systems. First developed to be used in aircraft as an information display source, the information was projected into the windscreen and pilots could read it without divert his focus from the windscreen. It work rather good in aircrafts as the windscreen background is generally a clear sky as in opposite to cars where the background is constantly changing, so drivers could not read such information as clearly as in aircrafts, therefore this shows an example of a not so well performed transfer of technology.

10. Explicitness

It is important to design products that are clear in how to use them. Consider a simple example, door design in public buildings. One must decide whether or not a not must be pulled or pushed. Here is where design makes the difference. When doors show a flat metallic plate this indicates that the door should be pushed whilst if the door has handles then it should be pulled.

Another example where explicitness is important happens in computer programs, where for example in word typing programs the icon with a drive on it is most likely to be the save function whether the icon with a printer and the label “PRINT” on it is most likely to be the print document function. For users, functions are probably clear from their label or name.
Representational icon design easily increases interface usability has it comes very intuitive for the user to understand their function.

Mobile applications Usability

More specifically in terms of usability, and in the interest of this study, comes mobile applications usability. This will be further explored recurring to the explanation of some usability attributes necessary for mobile application usability evaluation.

Mobile application, as a new technology sector, uses previous usability attributes and guidelines from desktop studies. However due to mobile devices special features, one must adapt guidelines and attributes to mobile applications special requirements. According to previous usability literature and usability studies on mobile-applications one can highlight eighth generic usability attributes for mobile application usability measurement as shown in Table 2.1 (Finstad, 2010; Seffah et.al., 2006; Danesh et al., 2001; Nielsen, 1993; Oquist & Goldstein, 2002; Ziefle, 2002 *apud* Zhang & Adipat, 2005).

2.1.3 Design Concepts

The following two design concepts aim to help developers to acknowledge user needs and instill usability into the development process of their applications. In the interest of this study User-centered design (UCD) served as the basis of the UsaGame, as the checklist aim to instill UCD into the development process of the touch mobile game applications.

User-centered Design

UCD is a well know methodology for product development that focuses on user characteristics and needs. This methodology should be applied in the early stages of the product development process, so it can contribute to a more pleasant and easy-of-use software applications fitting the correct user requirements (Averbouk, 2001; Nunes, 2006 *apud* Simões & Nunes, 2012).
According to (ISO13407, 1999), UCD can be divided into four groups of activities (Jokela, Iivari, Matero, & Karukka, 2003; Simões & Nunes, 2012):

1. Context of Use – know the user and his tasks as well as the context of use;
2. User and Organizational Requirements – the stage where these concepts are specified;
3. Design and Implementation – in this stage design solutions are created and implemented;

4. Usability and implementation – In this final stage the usability of the design is evaluated against user's requirements.

Table 2.1 - Usability attributes In Mobile Applications
***Adapted from:* (Zhang & Adipat, 2005)**

	Usability Attributes	Measurements	Observations
1	**Learnability**	Amount of time used to finish tasks at first use **(2,3,4)**	How easily users can finish a task at first try, also known as ease of use **(1)**
2	**Efficiency**	Task completion time; Time used on each screen **(2,4,5,7)**	It is different from learnability in terms of previous experience with the applications in this case **(1)**
3	**Memorability**	Time, number of clicks and steps used to complete a task after a non-utilization period **(4,7)**	If the applications has recognizable criteria and interactions that users can easily re-accomplish, this would be an advantageous feature **(6)**
4	**User Satisfaction**	User's attitude towards applications level of confidence, like/dislike **(4,5,9,10)**	User's perception, feelings and opinions of the product **(8)**
5	**Effectiveness**	Number of errors; error level of severity; Time spent correcting those errors; percentage of completed tasks **(2,4,5,7,9,10,11)**	Comparison between user performance and predetermined levels; useful for new application's assess improvement **(1)**
6	**Simplicity (Complexity)**	Amount of effort to find a solution: Number of menu levels that users have to go through to solve a task, Number of clicks to reach a certain page **(4,5,6,9)**	Degree of comfort that users complete tasks; Used to assess the quality of menus and navigation design; Capability of the applications to help users complete their tasks in a minimum number of steps **(1)**
7	**Comprehensibility (Readability)**	Reading speed or percentage of correct answers **(7)**	Ease with which visual content is understood **(6)**
8	**Learning Performance**	Measures the learning effectiveness of users **(12)**	Normally associated with applications for learning or communication with learners and instructors **(1)**
1- (Zhang & Adipat, 2005); 2- (Killi, 2002); 3- (Parush & Yuliver, 2004); 4- (Ziefle,2002); 5- (Chittaro & Cin, 2002); 6- (Seffah et al., 2006); 7- (Oquist & Goldstein, 2002); 8- (Rubin, 1994 *apud* Finstad, 2010); 9- (Christie et al., 2004); 10- (Nielsen, 1993); 11- (Finstad, 2010); 12- (Luchini et al., 2001, 2002, 2003)			

To better understand UCD concept the following Figure 2.2 will illustrate a UCD diagram and life cycle.

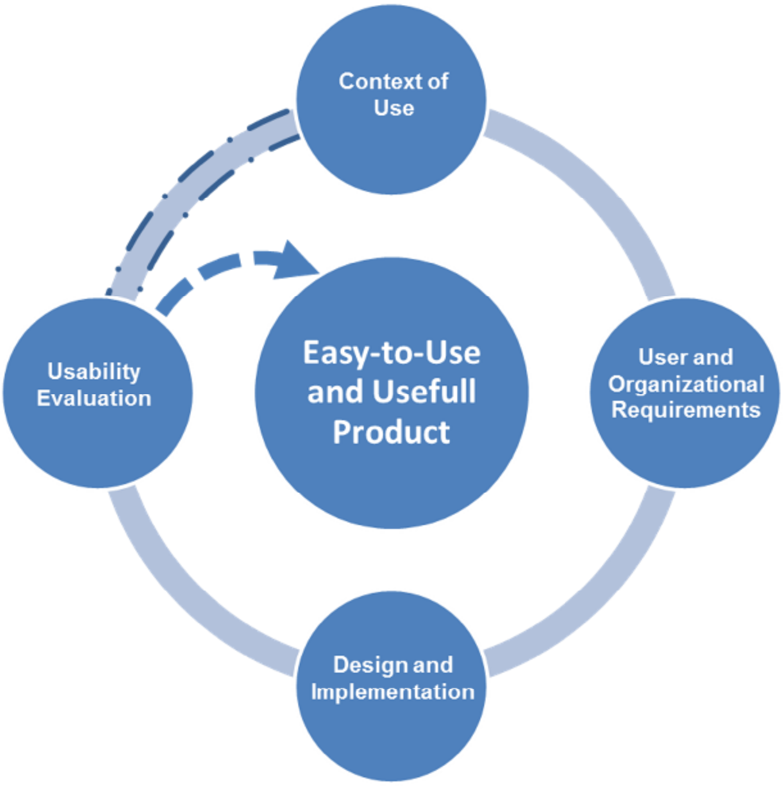

Figure 2.2 - Activities of user-centered Design
***Adapted* from: (Simões-Marques & Nunes, 2012)**

Focusing on users represents a great effort from designers, particularly when it comes to mobile device users. Understanding the main target of applications is becoming a more time consuming topic, since it could determine whether or not the applications will become an intuitive and pleasant experience for users. Especially in applications with a wide range of features, basic user research, such as, surveys and interviews are even more relevant. UCD aims for the usability evaluation of user interfaces to achieve usability attributes, such as, ease of use, user satisfaction, memorability, and efficiency (Nielsen, 1993).

User-Experience Design

Current UCD practices still pose some challenges, which limit the ability to make greater contributions to product development. Over the last years the design of the UX in developing interactive systems has increased (Mahlke, 2005). Progress has been made in order to improve UCD practices and increase UCD influence in product development, consequently UX professionals are more and even earlier involved in product development (Xu, 2012). UX is another term widely mentioned in contrast to usability. Although some people use both the terms interchangeably, UX is much broader concept than usability (Saffer, 2007 *apud* Heo et al., 2009).

According to (Norman, 1999 *apud* Mahlke, 2005) UX can be described as a concept that encompasses all aspects of users' interaction with products (Norman, 1999 apudMahlke, 2005).

UX is a much broader concept than UCD and is beyond UI design and usability. Understanding the UX ecosystem clarifies the definition given before. First users receive their UX from a product lifecycle, throughout different interaction stages, in early product marketing (how it is perceived, the use of the product (easy-of-use), training and help (how it is learned), support, upgrade, and so on. Secondly, users receive UX through all their interactions (touch points) with products during UX lifecycle stages, such as, functionality, workflow, UI design and usability, training, user support. Touch points may coexist in a single UX lifecycle stage. The following Figure 2.3 shows a diagram that expresses the concept of Total User Experience in a UX ecosystem.

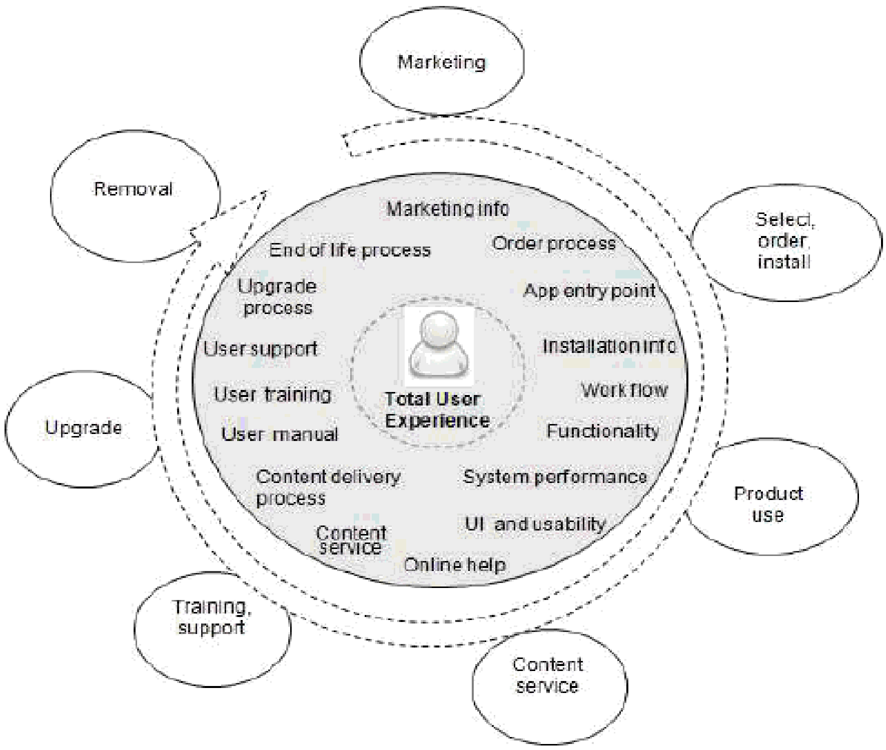

Figure 2.3 - Total user experience concept in a UX ecosystem concept
***Retrieved from*: (Xu, 2012)**

UX ecosystems can vary, whether in scale and nature of product domains. Users receive total UX throughout a continuous process involving all interaction touch points with products during its UX lifecycle, and breakdowns on these touch points would have a negative impact over the total UX, which can affect an optimal UX. One of the main aspects of UXD is to take user's feedback into account and incorporate them into the product development process. This leads to an evolution of the UX over time, due to product advance and technology improvements which influence user needs and usages. In today's competitive markets, whoever captures an innovative UX landing zone finds itself in a favorable position to create new products to win the market. However to find market opportunities current practices sometimes fail to achieve an actual UX, because data collection are based on user opinions and preferences. Considering previous reasons, it becomes important for UX experts to have an early involvement in product development in order to establish an innovative UX (Xu, 2012).

Many different approaches have been made to fully understand and consider other aspects of user's interaction with products. For instance, according to (Hassenzahl, 2005 *apud* Mahlke, 2005) one can differ non-instrumental quality aspects and others that take into account affect and emotions, during people's experience with products. Non-instrumental quality aspects can be further divided into hedonics, aesthetics and pleasure related. Hedonic aspects are considered important aspects relatively to users' product choice. Aesthetics also play an important role in product decision, since what is beautiful can be related to usable devices (Tractinsky, Katz & Ikar, 2000 apud Mahlke, 2005). According to (Jordan, 2000 *apud* Mahlke, 2005) pleasure and fun related aspects also come as important to enhance user's interaction with products. Even though, one should not confuse easy to use with fun to use as long as they might appear the same. Affective and emotional reactions play another important role on UX.

2.2 Usability Evaluation

Usability evaluation becomes essential to develop high usability products. An example of a high usability intended product is the mobile phone. (Kangas & Kinnuen, 2005 *apud* Heo et al., 2009).
Usability evaluation is suffering new challenges and should be questioned whether the classical concept of usability is still valid, how can it be measured. There is a need for a renovation in evaluation methods to become contemporaneously adapted (C. Wiberg et. al., 2009 *apud* Rusu et al., 2011).

There are different usability evaluation methods and even though some previous studies differ upon how many one should adopt (Ivory & Hearst, 2001, Rusu et al., 2011 *apud* Heo et al., 2009). Being that there are three general types one can classify usability evaluation: usability testing, usability inquiry, and usability inspection (Karat, 1997; Zhang, 2003 *apud* Heo et al., 2009). In usability testing users are engaged to complete certain tasks and then the UI is evaluated concerning the support that the interface gives to users in order to do their tasks. Usability inquiry bases upon observation of users whilst using the interface in real world settings. Also inquires users and acknowledge their answers to better knowledge of user's feelings towards the interface. Lastly usability inspection methods are based on usability professional's experience to report problems. Two typical methods are heuristic evaluation (HE) and cognitive walkthrough (CW) (Heo et al., 2009; Rusu et al., 2011). Evaluators play a critical role in these evaluations, therefore their ability to find usability problems might differ. One of the main causes for this is a vague evaluation criterion which results in subjective evaluation. In addition if a Usability checklist is too abstract then evaluation criteria might become more ambiguous (Hertzum & Jacobsen, 2001; Molich et al., 2004 *apud* Heo et al., 2009).

Methods for effective usability evaluation of mobile phones can become an open question about the one to choose (Jones and Mardsen, 2006 *apud* Heo et al., 2009) . An appropriate method should be chosen taking into account evaluation purposes, time, measures to be taken, among others (Lavery et al., 1997; Hartson et al., 2003 *apud* Heo et al., 2009)

In addition usability evaluation methods help identify usability problems and therefore could provide better design ideas.

2.2.1 Usability Metrics

Usability metrics will become important for usability game tests and their implied usability. Metrics are ways to measure and evaluate particular things. In usability the major metrics concerns are among the following: task success, user satisfaction and errors. Usability metrics even so from different areas require agreement in terms of how it is measured and need to be consistent. Therefore the same set of measurements must be assured each time measurement happens so results can become comparable (Tullis & Albert, 2008).
Most usability attributes mentioned before adopt self-reported data as mean to obtain desired information. Normally in this type of method the best way to capture data is to use some sort of rating scale. The two most used rating scales are a Likert Scale and a Semantic Differential Scale.

First Likert Scales are based on a statement used to determine the level of agreement. It can be either positive or negative, however a 5-point scale is normally used to provide a neutral response as one can see in the following example: 1- Strongly disagree; 2- Disagree; 3- Neither agree or disagree; 4- Agree; 5- Strongly agree. Many variations of Likert Scales are still in use, most purists claim two main Likert Scales characteristics, (1) it determines the level of agreement with a statement; (2) it has an odd number of possible answers to provide a neutral choice (Tullis & Albert, 2008).

Secondly Semantic Differential Scales involve the use of opposite pairs, or antonyms, adjectives to express user's agreement (level of concordance). Much like Likert Scales this type of scale also uses a 5-point or 7-point, to allow a neutral response. On the other side, Semantic Scales may be more difficult to create, since sometimes it is hard to find proper opposite word to fit in the scale (Tullis & Albert, 2008).

For the usability evaluation test that will be further explained in this study it were implemented Likert scales for users to grade some important criteria, such as, overall satisfaction and usefulness of an application.

2.2.2 Heuristic Evaluation

Invented by Jakob Nielsen, HE involves examining the conformity of an interface with usability principles (Pack, 2001). Heuristic evaluations will serve as one of the bases for the adaptation and creation of Touchscreen mobile game applications guidelines.
HE is an inspection method broadly used due to its easy implementation, low cost and ability to report usability problems whether major or minor problems. Thus it's widely known it still is possible to miss domain problems, therefore the need for appropriate heuristics is very important. Especially for applications based emerging technology, the creation of new heuristics becomes a necessity to follow usability requirements. In addition due to the probability of missing domains, HE should be complemented with other usability evaluation methods especially usability tests (Rusu et al., 2011).
HE is based on the opinion of what is good and bad about a specific interface. Normally such evaluations are formed based on people's common sense and intuition however ideally they should be made according to certain rules or guidelines. The objective is to encounter usability problems in an interface. Those problems then are forward to become part of an interactive design process in order to accomplish problem's solving. HE engages a group of evaluators to examine the interface and report its conformity with usability principles (Nielsen, 1993). Heuristics are more norms and recommendations than usability guidelines, since they come for experience based problems (Nielsen, 2005). The following Table 2.2 of heuristics is based on ten general usability heuristics and two more adapted to mobile phone usability.

The number of evaluators depends on cost-benefit analysis, one evaluator can perform HE on an interface but it is most likely to miss most of usability problems in an interface. The more, the better, especially when usability is critical or when dealing with large investments. Independency of evaluators must be assured upon HE. Evaluators are allowed to communicate, and their findings aggregated only upon all evaluations have been accomplished, in order not to compromise the evaluation tests. Evaluations can be performed with an observer present, which will increase test report conclusion, and also help evaluators with any problems throughout the HE. Reports of this kind of evaluation are normally a list of usability problems in the interface, correlated with the usability principles that failed (Nielsen, 1993).

Withal there are two major different with HE and traditional user testing. First, there is compliance from observers to answer questions from evaluators, during the evaluations. Second is the opportunity that is given to evaluators to receive hints on using the interface. In traditional testing observers want to find out errors users make whilst using the interface. Therefore users are entitled to discover the solutions to their problems throughout the experiment. In other hand, in HE, evaluators can be elucidated about their questions. In addition it is worth mentioning that users must not be given help right away, first they must have acknowledge on the usability problem in question (Nielsen, 1993).

At long last, this method does not provide guarantees of problems solutions or even perfect results, but it will most likely help on generating a revised design according to the analysis of the principles that were violated (Nielsen, 1993).

Table 2.2 - Twelve usability Heuristics
***Retrieved from:* (Inostroza et al., 2012; Nielsen, 2005)**

Heuristics	Explanation
Visibility of system status (2)	System should keep users informed about what is going on, through feedback within reasonable time.
Match between system and the real world (2)	System should speak users' language, with words, phrases and concepts familiar to the user. Follow real-world conventions, making information appear in a natural and logical order.
User control and freedom (2)	Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having an extended dialogue. Support undo and redo.
Consistency and standards (2)	Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.
Error Prevention (2)	Better than good error messages is a careful design which prevents a problem from occurring in the first place; either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.
Recognition rather than recall (2)	Minimize user's memory load by making objects, actions, and options visible, the user should not have to remember the information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
Flexibility and efficiency of use (2)	Accelerators - unseen by the novice user - may often speed up the interaction for the expert user that system can cater to both inexperienced and experienced users. Allow users to tailor.
Aesthetic and efficiency of use (2)	Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
Help users recognize, diagnose, and recover from errors (2)	Error messages should be expressed in plain language, precisely indicate the problem and constructively suggest a solution.
Help and documentation (2)	Even though it is better used without documentation, it may necessary to provide help and documentation. Such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.
Customization and shortcuts (1)	System should provide configuration options, to allow customization and set shortcuts. Also should allow sorting and the creation of groups of elements.
Physical interaction and ergonomics (1)	System should provide physical buttons or similar for main and/or recurrent functions, placed in recognizable places. Device's dimensions, shape, weight and buttons displacement should fit normal postures of the users' hand.
1- (Inostroza et al., 2012) ; 2- (Nielsen, 2005)	

2.2.3 Cognitive Walkthrough

First proposed in 1990 by (Lewis et al., 1990 *apud* Mahatody, Sagar, & Kolski, 2010) it has since then evolved and used in many usability studies. Despite many variants created that derive from the traditional CW, the basic principle stays the same. CW aims to register user's cognitive behavior by responding to questions related to user's cognitive model.

CW is one of the usability inspection methods and consists basically in two phases. In the preparation phase evaluators use the interface to perform tasks and build a task report, which a normal user will further need to accomplish. Evaluators can be designers, usability inspection experts or even users. In the evaluation phase each action is taken and user's feedback is registered, through predetermined questions related to user's expectations, use reality and method's cognitive model. CW besides focusing on basic usability principles (e.g., satisfaction, effectiveness) also focuses on user's opinion whilst performing each task and operating with the interface (Mahatody et al., 2010).

Even though it maintains its theoretical foundations, CW has been evolving due to its practical value and to follow the progress in the field of Human Machine Interaction and its many fields of application. (Mahatody et al., 2010) describe at least 11 of CW variants, but in the interest of this study, one can be chosen to fit the needs of this study. In that being Cognitive Walkthrough with Users (CWU) will be chosen.

This variant of CW integrates users into the process and can be divided into three phases of implementation. First CWU is performed has the traditional CW previous explained. Secondly users are integrated into the process, where users must be representative and fit the target public. Following a brief introduction about the interface and the tasks itself, users start all tasks defined in the walkthrough. During this phase users are invited to express their thoughts, feelings and difficulties, regarding that no further help or explanation is given what so ever. At the end of each task users' note the main difficulties encountered. Upon completing all established tasks, they are asked to comment on the problems identified whilst performing those tasks. As a final point in the last phase, evaluators (usability experts) review all users' doubts and notes with the intent to further solve all usability problems (Mahatody et al., 2010).

CW can be applied in system design and development phase, to identify usability problems, or also after the product has been developed to test for difficulties in executing specific tasks. Even though CW has some methodological weaknesses, such as, evaluator training, task analysis and context considerations, it still can be very effective if proper variants and adaptations are taken into account with the type of system to be applied into. The fact that CW can be effective in one system does not necessarily mean that it can be effective in other systems (Mahatody et al., 2010).

In order to adequately validate and test the effectiveness of this study proposed checklist one needs to submit usability evaluation tests to a Game application. CW will serve the basis of the Game test protocol to be followed by test participants.

2.2.4 Usability Testing

Once upon mobile applications usability testing there are two major methodologies to be applied, laboratory experiments and field studies. Laboratory experiments recreate controlled settings where mobile applications can be tested throughout human performed tasks, whereas field studies accede to give users the possibility to tryout mobile applications in a real environment (Zhang & Adipat, 2005).

Laboratory experiments represent a very advantageous method of performing usability testing of mobile applications (Bautsch-Vtense et al., 2001; Buchanan et al., 2001; Buyukkokten et al., 2002 *apud* Zhang & Adipat, 2005). Laboratory controlled environments allow tester to have a full control over an experiment. One can be assured that predetermined tasks are followed up by participants. Also in these experiment tests we can have control over user's actions which can be crucial to control results. In these experiments it is easier to measure usability attributes and interpret results, and is a very helpful method for data entry research mechanisms in mobile devices. Consider for example, if the objective is to study the effectiveness of data entry methods whilst users are moving around, laboratory experiments come as the appropriate method since testers can ensure that users are walking around. Environment controlled experiments allow the possibility to use video and audio recording, needed to capture participants reactions and emotions (Dumas & Redish, 1999 *apud* Zhang & Adipat, 2005). In addition video recording is useful for eye tracking movements which are important for key locations analysis.

Field studies take mobile context and unreliable mobile wireless network connection into account by performing usability testing in real environments. Participants experience in this type of tests in real environments allow a more reliable perceived usability than laboratory experiments as its context is based in real life experience situations (Kjeldskov & Stage, 2003; Palen & Salzman, 2002; Sharples, Corlett, & Westmancott, 2002 *apud* Zhang & Adipat, 2005). Notwithstanding this methodology strength it still has some drawbacks - First, create real environments that capture the entire richness of mobile context might be complicated. Second, applying evaluation techniques, such as, observation and verbal protocol, can become difficult during test evaluation. In addition, due to the participants movements as they move around imposes challenges upon data collection and control over participants. Therefore these factors are sometimes hindrances to an effective data collection in field studies (Zhang & Adipat, 2005).

According to (Zhang & Adipat, 2005) laboratory testing is more appropriate for stand-alone mobile applications – without the direct need for network connectivity. Nevertheless in laboratory environments network connectivity is at the desired strength and reliability, testers can focus better on evaluating mobile components, such as, keys layout, menus design and link structures and data entry methods, which are not dependent on network connectivity. Whereas field studies are more suitable for usability evaluation of performance issues related to mobile context. For instance, mobile context has a great impact on network browsing throughout mobile devices therefore a field study would better evaluate the application's performance (H.Kim et al., 2002 *apud* Zhang & Adipat, 2005).

Better suited approach for mobile applications

Taking into account the two previous studies and the interest of mobile applications usability study, Laboratory experiments may come as the best suited approach. Laboratory experiments allow more ease access to data collection techniques, such as, think aloud observations, video recording and user's action observation (Kaikkonen et al., 2005). Despite technology advances allow the possibility to have access to data information in field studies, such as, portable video recording and data transmission devices, nevertheless they are more likely to become more time-consuming studies than laboratory experiments (Kjeldskov et al., 2004 *apud* Kaikkonen et al., 2005).

For UI evaluations of mobile applications and devices, field studies may not add significant value to the validity and power of the test to find possible usability problems and also the effort required to perform field studies is also higher than laboratory ones. In what concerns mobile game applications due to their entertainment nature, they are normally operated in steady still positions. Users normally do not move around whilst playing mobile game applications since their attention is entirely focused on the game itself. In this interest, laboratory experiments allow for users to concentrate on their tasks. Therefore laboratory experiments come as an advantage since they can test normal playable conditions and even reduce the amount of time necessary to perform those tests. Lastly laboratory experiments provide sufficient information when dealing with usability testing of mobile applications (Kaikkonen et al., 2005).

2.3 Mobile Devices

Mobile devices, referred to as devices that can be operated in a mobile context, with the overall advantage of being portable. These devices can display information, whether text or media, and allow the possibility to have a wireless connection to the network, with limitations, basically everywhere. Mobile devices face an up growing market and an extremely technology alliance that permit these devices to become more and more advanced. Further it will be given examples and explanations of the many shapes and formats of touch mobile devices existing on the time being.

2.3.1 Mobile Devices' Unique Features

Mobile devices have some limitations due to their unique features. These limitations pose challenges to usability evaluation on mobile applications. According to (Zhang & Adipat, 2005) the following features determine those challenges:

Mobile context is related to the characterization of the interaction between users, applications and the surrounding environment (Dey, Salber & Abowd, 2001 *apud* Zhang & Adipat, 2005). It normally characterizes the location, objects and environmental elements that can divert users' attention. All environmental context aspects are very difficult to include in usability testing, therefore different tests must be performed (Longoria, 2001 *apud* Zhang & Adipat, 2005).

Wireless connection is sometimes a hindrance for mobile applications due to slow and unreliable connections (Longoria, 2001 *apud* Zhang & Adipat, 2005). These aspects affect data downloading time, quality of streaming, and can vary from location to location.

Screen size is normally significantly smaller than desktop computer, which constraints the ability to display all information and affect usability. Especially in Web pages, where there is a significant amount of information to be displayed, this feature becomes relevant.

Display resolution is normally less more supported in mobile devices, which can decrease the quality of information displayed in the screen. Notwithstanding this fact, technology advances in a pace that allows mobile devices to have an increased resolution, resulting in increased usability.

Limited processing and power are two main aspects that distance mobile devices far behind from desktop computers. Processing capability dictate the amount of graphic support and speed that mobile devices can have, which can become increasingly important in game applications. Power supplies can vary from mobile devices, but generally they become a hindrance for mobile use, since it cannot last for many periods of time.

Data entry aspects can become very difficult in small devices and sometimes require a certain level of proficiency (Longoria, 2001 *apud* Zhang & Adipat, 2005). Users' context (e.g., walking, sitting, operating with one thumb) can increase the difficulty for data entry methods. Different data entry methods (e.g., soft keys, physical keyboards, touchscreen devices) can result in different usability evaluations. Multimodal mobile applications enable to combine voice and touch as a data input and receive spoken output (e.g., Siri software in iOS systems). These emerging applications enhance UX with mobile devices. Features such as key size, location and spacing (further explained) have a direct impact on data entry usability (Park & Han, 2010).

All these previous features pose physical restriction problems that while designing and developing mobile applications these issues must be held into account.

2.3.2 Mobile Applications

Mobile applications are software applications for mobile devices, whether business, practical, or entertainment related they face a fast evolution. For example there are different applications that brought internet access to mobile devices and other more business related, that allow access to mobile banking services permitting customers to check their account movements and make payments or transactions, through their mobile phones (Kaasinem et al., 2000; Varshney & Vetter, 2002; D. Zhang, 2003 *apud* Zhang & Adipat, 2005).

The high demand and fast growth of mobile devices increased research interests on mobile applications, as many innovative mobile applications emerge. Ease-of-use, user satisfaction and effectiveness are critical factors in a competitive mobile applications' market. The fast growth and market competitive increases the importance to conduct usability evaluations to provide better and more usable applications.

More specifically in the interest of this study are placed the game applications part of the entertainment applications. These applications allow for example, for users to watch videos or images, and play interactive games in their mobile devices. Due to users' satisfaction importance in mobile applications, performing usability testing is a mandatory process to achieve a high user satisfaction and ensure that applications are practical, easy to use and effective (Zhang & Adipat, 2005).

2.3.3 Design Usability Websites for Mobile Devices

The world has been evolving following up the mad rush to get online. Since the growing expansion of the internet, today it is possible to access the web almost everywhere. This allied to the growth of the Smartphone market, contributed for the evolution of mobile web.

When compared with yesteryear were there was a lack of best practices, and guidelines to design user-friendly websites, today usability is not unknown anymore, and allows designers to acknowledge the user difficulties with the website.

Designing for mobile is sometimes more challenging than is for the web, it is extremely important to incorporate the useful features about the site and to know how to select the non-needed ones (Seward, 2011a).

As in web design, mobile applications developers faced themselves with different mobile devices and therefore the need to adapt or create specific software mobile applications for each device. The forward methodologies known in the web design field can also be applied to mobile applications development.

Progressive enhancement vs. Graceful degradation

Web producers have mainly two options in web designing: progressive enhancement or graceful degradation.

Graceful degradation (GD) is a web technique that allows all users even with less-than-optimal software to access websites in which the advanced effects will not work. The website is built to recognize the access by less capable technology and removes some features. This focuses primarily in the mainstream or better technology and then skips to less capable devices (Heilmann, 2009).

When applying this technique two rules must be assured, that any browser can view the content of the website and can navigate the following. Designers must have in mind that whatever special effects they add to the websites the site still as to be usable without them (Koch, 2002).

Progressive enhancement (PE) is the opposite of the GD – starts with the basic and then adds capability and new features as the capacity increases. This reflects on better websites focusing on the content first and then on presentation. When it comes to content PE wraps around what is essential and offers a great level of detail to basic users. The accessibility is better, whereas content is available to all users and any browser while providing enhanced versions for those with more advanced browser software (Gustafson, 2008).

Making an analysis to these two techniques, both are valid and are used for the same purpose of building websites with usability (Olsson, 2007). But PE can be seen as a better technique than GD, right since the beginning of the code it puts user's interest first, and covers up a wide range of potential issues and features, built-in the baseline code. Thought PE requires more initial work and learning it still allows users to experience all important qualities even in less than optimal devices (Kappert, 2011). In what regards mobile device's context PE might come as the best design tool. Consider for example the iPhone and iPad devices, both can support mobile applications. Nevertheless the small screen of the iPhone device when comparing with the iPad might come as a design challenge. Therefore progressively adapting the mobile application needs to the mobile device might come as the best design tools as it will assure that every mobile device can execute the mobile application properly.

Dan Seward (2011a) suggests a few guidelines useful for usability design in mobile websites that are presented in Table 2.3.

2.4 Touchscreen Technology

In this chapter touchscreen technology will be further explained in detail, with some examples of the most used technology in order to acquire proper knowledge about this technology for further notice and aim to create more suited usability guidelines to this technology.
Touchscreens are visual displays that can detect touch inputs and therefore locate the exact position of the touch, so keys displayed on the screen can be selected. Touchscreens can also sense other objects, such as, stylus, that can be used in all the further explained touch

technologies, with the exception of capacitive technology, that can only support special touch stylus.

Table 2.3 - Usability mobile website guidelines
***Retrieved from*: (Seward, 2011a)**

Guidelines	Brief Explanation
Remove unnecessary material	Images can enrich websites but only if properly used;
Access Full-site and Back	Provide links to the full-site and to the mobile version;
Single-column layout	Stack elements in vertical, and if possible in only one column;
Use of high contrast visual elements	Text information must be clear and readable, also links must be easy to target;
Critical features at page top and bottom	Provide critical features, such as, search bars at page top and bottom to be easily access;

When first appeared in the market, touchscreens where labeled as an exotic, expensive and rather unpractical and time consuming technologies. Nevertheless with the expansion and development of this type of technology that preconception has changed, and many companies within a wide variety of industries have been acknowledging the advantages of implementing touchscreen displays in their products (Elo, 2012). Examples of this successful technology is the increased Smartphone adherence and in tablets growing market.

Touchscreens as known today as a new technology actually date back to the late 1960s. E.A.Johnson invented in 1965 what is believed to be the world's first touchscreen that was used for air traffic control in the U.K. and was the precursor for touchscreen development. But the first to be widely known was the PLATO IV, an infrared touchscreen panel used in the University of Illinois as part of the PLATO educational computer systems. Since then touchscreen technology was developed in many forms and shapes such as, wrist watch, personal communicator phone, gesture operated keypads, until as we know today (Cohen, 2011). Another example of a touchscreen is the Lumen. Developed by (Poupyrev, Nashida, Maruyama, Rekimoto, & Yamaji, 2004) Lumen is an interactive device in which each pixel has height, also known as an RGBH display, where RGB is a color model and H is the height of a pixel. The device can display simultaneously two-dimensional graphical images and dynamical 3D shapes. The shapes can be viewed or touched and with a built-in two-dimensional position sensor (Smart Skin) the interface becomes interactive, which enables users to manipulate and modify shapes. Some devices use actuators on the display to improve usability of touch panels.

Providing the user feedback through vibrations becomes useful especially during noisy situations (Fukumoto & Sugimura, 2001).

Touchscreens can simplify user interaction and make it more intuitive and more "user friendly".

Within a wide range of benefits and drawbacks the following can be highlighted which are presented in Table 2.4.

Table 2.4 – Examples of Benefits and Drawbacks of Touchscreen technology
***Retrieved from:* (Display, 2001; Elo, 2012; Parikh & Esposito, 2012)**

Benefits	Drawbacks
Fast access	Not suited for extended data entry
No need for external mouse or keyboard	Constant visual attention
Outcome better customer services	Ergonomic issues
Suited for menu based applications	Lack of haptic feedback
Simplest,direct and intuitive	Neck fatigue
Outstand harsh environments	Wrist and finger fatigue
No wasted space	
Reduces devices footprint	
User configurable	

These guidelines showed in Table 2.4 take part in literature review to increase knowledge to create touchscreen mobile application guidelines. Both benefits and drawbacks where held into account to adapt the usability guidelines to touchscreens. The proposed guidelines will be further shown in chapter 4.

2.4.1 Most Used Touchscreen Technologies

Regarding Touchscreen displays there are different types of technologies to manufacture Touchscreens displays. Different types of touchscreen technology can have different utilizations and can become better for some types of activity than others. Further comparison of these types can be seen in Table 2.5. Therefore I choose to explain four types of touch technology: resistive; Surface Acoustic Waves (SAW); Capacitive and Infrared.

Resistive

Resistive touchscreens are one of the most used touch technologies, due to its simple structure (Broz et al., 2012). There are different types of resistive touch technology, nevertheless they are made similarly. As shown in Figure 2.4 layer by layer they are composed by a glass substrate with a resistive coating of indium tin oxide (ITO), separated from another resistive coating through tiny insulating dots, plus a flexible membrane and a protective coating.

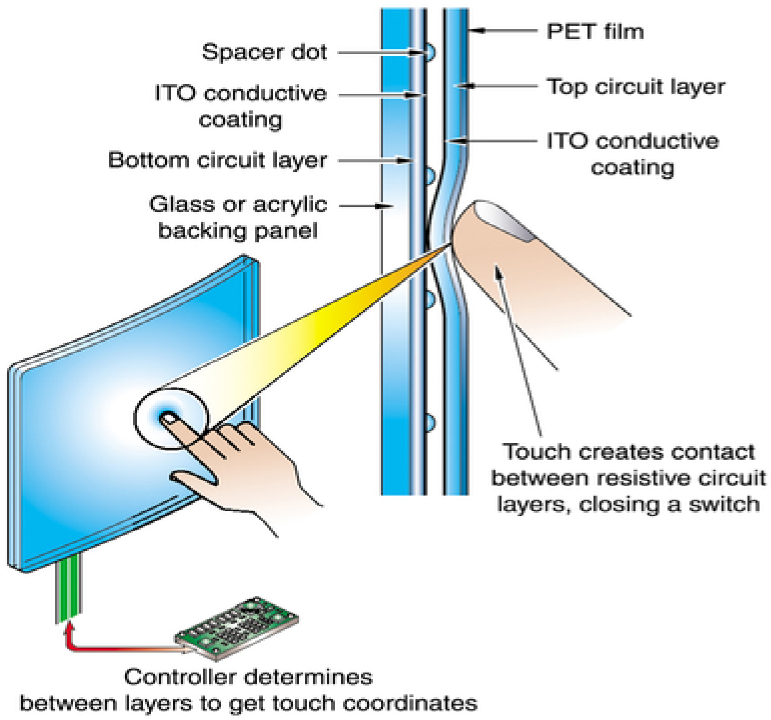

Figure 2.4 - Resistive Touch Technology
***Retrieved from*: http://www.tci.de/typo3temp/pics/b51ea4be59.jpg**

When the top flexible surface is touched, the screen compresses and the two resistive coatings come together forming a closed circuit. Within contact, voltage flows to each of the four corners and the resulting voltage from the touch is converted into X and Y coordinates by an electronic controller and then sent to the host computer.

Since it is force activated the flexible coversheet enables the touch to be registered by many kinds of input devices, such as gloved hands, fingernails, stylus, and credit cards. Due to the importance of the glass layer, the touchscreen can operate even if the coversheet is damaged or torn (Display, 2001).

Since both touchscreen and its implied electronic can be integrated into embedded systems, this type of technology is one of the most versatile and cost effective solutions making it ideal for many applications, whether industrial, point-of-sale or medical industry (DeVisser, 2007).

Resistive touch panels may seem the wisest choice of all, but nevertheless this technology still has two major drawbacks. First rugged environments can cause the glass support panel to break. Secondly the other weakness is the ceramic ITO conductive layer applied to the protective coating. This layer requires a very complicated development process, such as, highvacuum deposition, which increases its production costs and decreases its "environmental friendliness". Also the ITO layer degrades itself with repeated usage (DeVisser, 2007).

To eliminate these issues, a viable solution would be a flexible transparent touch conductor, which would provide a more durable interface and cost efficient development process. Such features will allow touch panels to extend their life time as well as open up new rugged applications for this technology. This has been put to proof with the development of an organic conductive polymer film, which an extended life time, up to five times the ITO layer. Also the manufacturing process has been improved, now is roll-coated onto the touch panel's PET (pixel extraction table) film. This process is more economical and eco-friendly, maintaining a surface resistance within the range of ITO coatings (DeVisser, 2007).

Capacitive

Capacitive touchscreens are well known for their combination of high durability, optical clarity and touch sensitivity. Capacitive panels are made by adding conductive coating to a clear glass sensor, unlike resistive panels, there is no top coating layer just the rigid protective cover. Then voltage is applied to the four corners of the screen along an X-Y axis. When the screen is touched voltage drops and the system recognizes a disturbance. Then the controller sends the X-Y coordinate to the serial port. Because the human body conducts current, fingers act as a second conductive layer (Broz et al., 2012; Display, 2001). This technology can be exemplified in the following Figure 2.5.

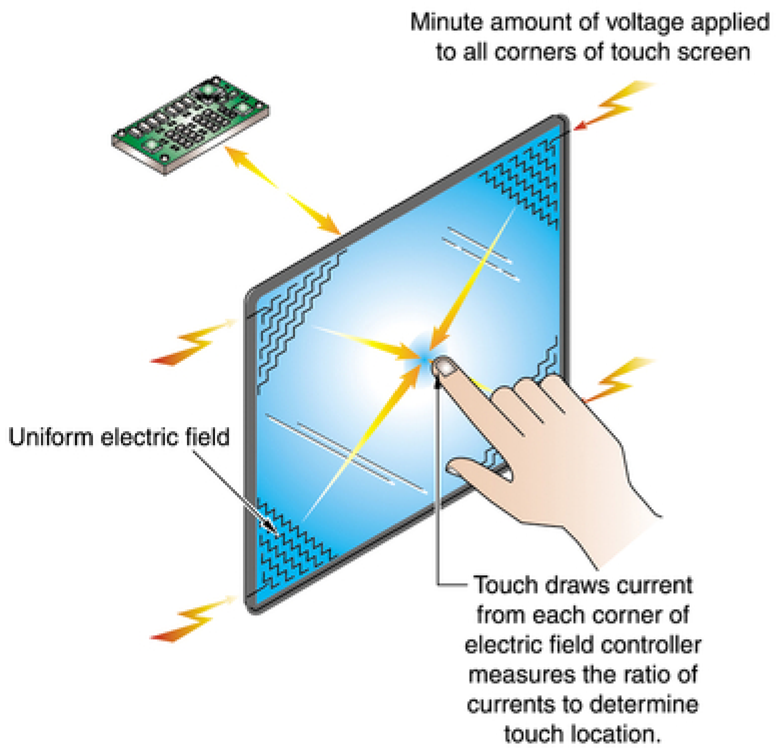

Figure 2.5 - Capacitive Touch Technology
***Retrieved from*: http://www.tci.de/typo3temp/pics/48f0cfff00.jpg**

These systems are mounted onto the monitor and can be sealed, providing a more durable and resistant surface to dust and dirt. Features like these allow capacitive touchscreen to be used on harsh environments, like gaming, vending, public kiosks and other industrial applications (Display, 2001).

Surface Acoustic Wave (SAW)

SAW touchscreens come as a similar technology to capacitive touchscreens, but with the advantage of being operated trough out many different inputs, such as stylus and gloved hands. Their structure is based upon ultrasonic wave emission and absorption. The touchscreen controller sends a five-megahertz (5 MHz) electrical signal to the transmitting transducer. Transducers placed along the X and Y axis, convert the electrical signal and generate sound waves that are propagated across the glass layer. When the screen is touched a portion of the waves are absorbed and the rest is reflected back to the sensors. The sensors can acknowledge if the wave has suffered any distortion based upon the time waves take to return to the source. According to this time the sensors can generate X and Y coordinates that are then transmitted into the computer to process them and activate desired functions. An example of this kind of technology can be further seen in Figure 2.6.

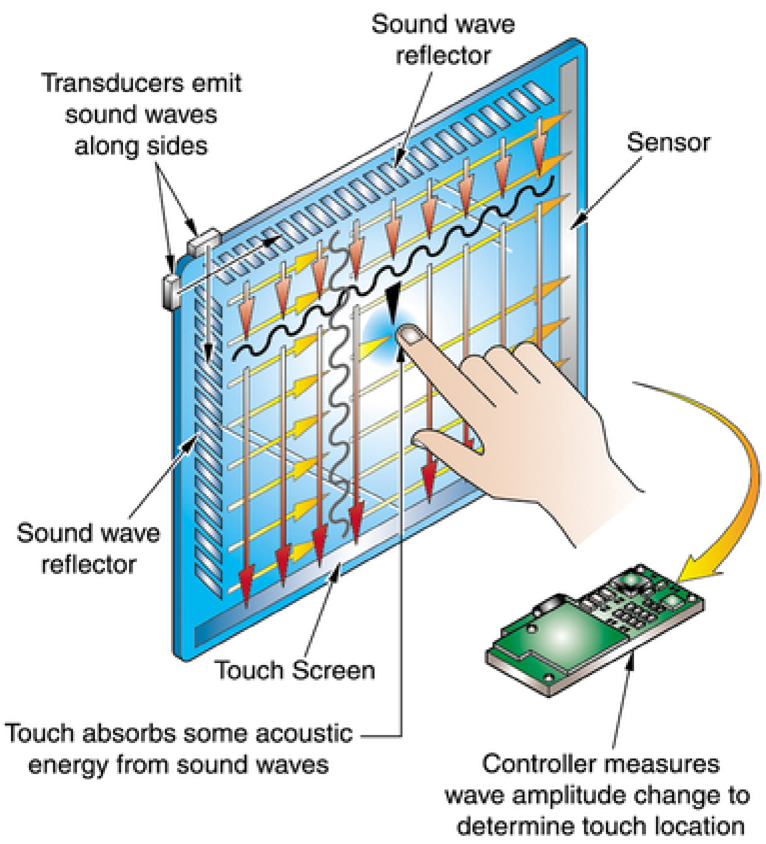

Figure 2.6 - SAW Touch Technology
***Retrieved from*: http://www.tci.de/typo3temp/pics/dedb3fb160.jpg**

Acoustic wave technology unlike others does not depend upon ratios to determine touch input location. This kind of technology is more stable, therefore providing a drift-free operation and increased accuracy.

Infrared Touchscreens

In Infrared screens a matrix plane of Infrared Light Emitting Diodes (IR-LEDs) is mounted onto a custom bezel into a CRT or LCD display screen. Photo transistors act as detector elements to acknowledge if whether or not the IR-LED beam has been broken or not. When a touch input occurs the light beam is broken and the sensors report the generated coordinate to the computer serial port (Display, 2001). Touch inputs can be performed using all types of touch inputs, such as, gloved hands, fingers, credit cards and so on. This type of screen does not require a membrane, just an array of LED and phototransistor detectors. Therefore the screen does not have any patterning and is totally transparent which results in increased optical clarity. Also in this type of technology if the plate is damaged it is not generally necessary to replace the entire touchscreen whereas in other touch technologies this might not be possible (M. L. Smith, 1990). An illustration of infrared touch technology can be seen in Figure 2.7.

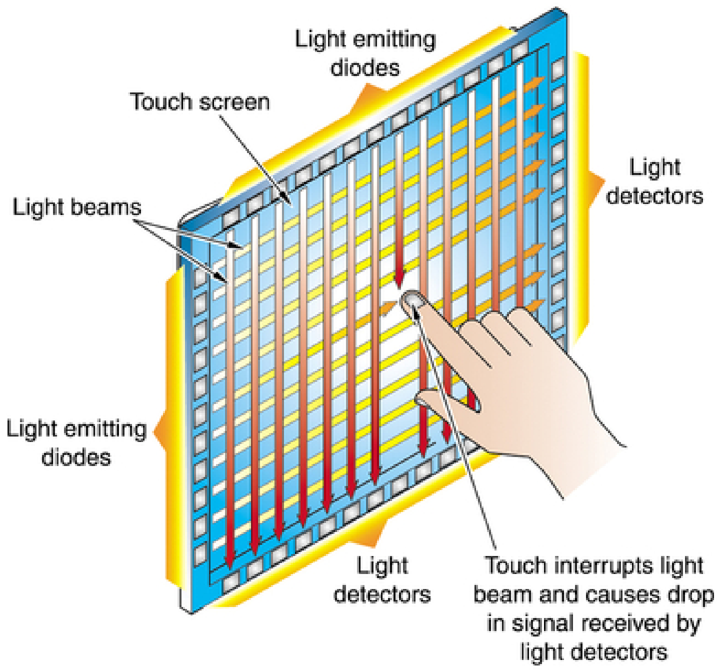

Figure 2.7- Infrared Touch Technology
***Retrieved from*: http://www.tci.de/typo3temp/pics/110cdf8101.jpg**

This technology was once used widely across the globe as an initial touchscreen technology, but even thought is has its shortcomings. Due to LED light beams it has premature touch detection problems and parallax problems, the latter happen especially in curved screens. Also

Conventional Infrared Touchscreens are suitable for use in battery-powered instruments, such as mobile devices, because of their high power consumption (Display, 2001; M. L. Smith, 1990).

Comparing Touch technologies

Based on (Sjöberg, 2005) one can make an improved comparison between the four kinds of touch technology referred previously as shown in Table 2.5.
As it can be seen in Table 2.5 , Resistive, Infrared and SAW technologies stand out in the input flexibility since they can be operated by many input types, whereas capacitive touchscreens can be used by finger input and only by special capacitive stylus. In terms of screen transparency and clarity Capacitive has an excellent performance as well as Infrared and SAW since these technologies have only one layer of glass.

Table 2.5 - Comparison between most used touch technologies
***Adapted from:* (Sjöberg, 2005)**

	Resistive	SAW	Capacitive	Infrared
Input type	Single touch	Single touch	Multi-touch	Single touch and no motionless capability.
Input Flexibility	Gloved hands, stylus, credit cards, and others.	Gloved hands, stylus, credit cards, and others.	Finger touch, special capacitive stylus.	Gloved hands, stylus, credit cards, and others.
Calibration Stability	Good	Excellent	Poor	Excellent
Transparency	87,5% transparency due to the extra layers.	Only one layer of extra glass.	One layer of conductively coated glass.	No extra layers.
Environmental tolerance	High tolerance to harsh environments.	Continues working if scratched but poor environmental tolerance.	Not tolerant to moisture and high humidity	Does not operate under dust and dirt.
Durability	Good, Long term degradation in ITO layer.	Excellent	High durability	Excellent

Environmental tolerance performance is one of the most critical factors in touchscreen decision making for public applications, such as outdoor kiosks, dusty environments among others.

Relatively to this issue Resistive panels and Infrared display come as the most tolerant to these kinds of environments, becoming suitable for outdoor usage. Nevertheless Infrared technology is becoming obsolete due to its low performance.

Touchscreen usage foster concerns about durability because of the amount of touch input suffered throughout its lifetime. In long term durability, resistive technology has a low performance due to microscopic cracks in the ITO layer caused by long term usage. Therefore Resistive and Capacitive stand out as the most beneficial technologies and are the most used ones. It is worth mention that the drawbacks of each technology must be held into account when developing mobile applications. As mentioned before Capacitive technology might not work with different input types which may become a hindrance to some applications, such as, Restaurant touch cash registers where the waiters are likely to use credit cards, pens and others inputs.

2.4.2 Touchscreen Technology Examples

This specific literature review aims to provide adequate knowledge about the main touch technology examples. Being the first two the ones with more interest for this particular study of touchscreen mobile game applications.

Smartphones

Smartphones characterize the latest step in portable and communication technology development. People carry multiple mobile devices to have mobile access anywhere, whether web browsing, entertainment or for communication purposes. Despite the broad range of multiple portable devices, such as, tablets, smartphones and even laptops, there is undergoing a heated debate in popular media, about the effectiveness of each one (Oulasvirta, Rattenbury, Ma, & Raita, 2012).

One is now faced with the selection of the device one should carry. Many may differ in opinions but nevertheless there is still a vague preference for smartphones as being the most important device (Shah, 2011), some examples of smartphones are shown in Figure 2.8.

Smartphones are becoming increasingly advanced and sophisticated; some may include dual-core processors, once only seen in laptops. Whereas laptop and tablets focus on web-browsing, e-mail and complex programs, smartphones focus until recently, on communication purposes. Smartphones have now power to offer some basic computing functions and tend to become even more advanced. Notwithstanding these facts there is still one main negative aspect about smartphones that is their reduced screen when compared to laptops and even tablets (Shah, 2011). Also their hardware is liable to suffer from limited memory, limited processing speed and energy reserves (Chun & Maniatis, 2009).

Figure 2.8 - Examples of Smartphones
***Retrieved from*: http://blog.basesoft.com.br/files/2012/05/smartphone.jpg**

In terms of time spent per day, smartphone's usage is increasingly over passing the time spent with traditional forms of computing. Even though its use is significantly shorter in duration and more uniformly spread throughout day time, it can be as twice as abundant in terms of total time. To corroborate smartphone's importance when compared to other mobile devices, users who have smartphones do not find tablets as "critical" or "must have" devices (Shah, 2011).

Tablets

Tablet devices are becoming more popular and more useful as time passes by. A great example of that is the iPad. Apple has shipped on the last quarter of 2011, 15,4 million iPads, leaving the PC manufacturer Hewlett and Packard on a close second with 15,1 million PC's shipped (G. Smith, 2012). Proofs of this growing market are the possibilities that these devices can accomplish, schools are requiring them to students, in some airline companies flight attendants are handing them out to passengers during flights, even some companies are adopting them for a marketing purpose, to showcase products to clients in a far better way. Some examples of tablet devices can be seen in Figure 2.9.

Tablets fill a niche between the PCs and Smartphones. They have all the advantages of a smartphone, except phone calls, but with a wider visual display and software capability but not quite matching up with PC standards. They are becoming widely used for multi-sharing tasks, marketing purposes, such as, video displays, and many other reasons. Nevertheless they are still not compared to smarthphones as they are to big totally mobile.

Figure 2.9 - Examples of Tablets
***Retrieved from*: http://www.infoescola.com/wp-content/uploads/2011/08/tablets.jpg**

Tablets foster security concerns

A great difference between mobile phones and tablets is the safety issue. Tablets are commonly shared between multiple people, which foster safety concerns in terms of private data release. Mobile phones are highly user personalized, and people find themselves leaving all sorts of accounts logged-in. Tablets are not that safe yet, shareable devices are easy to manipulate and report safety concerns in privacy data knowledge. For instance, desktop computers can be configured to have different user accounts and therefore be used without privacy data concerns for any users. The iPad for example does not have this feature as a result it cannot be used so easily or it should be used more wisely. Also these devices as well as smartphones do not match Desktop computer in terms of anti-virus performance.

Some differences and breakdown usages relatively to Tablets and PCs are summed in Table 2.6.

Table 2.6 - Tablet and PC comparison
***Retrieved from:* (Seward, 2011b)**

Tablet	PC
Web browsing Reading Casual computer usage Play games Email and social networking	Significant Text entry Shopping Multi-tasking (tabbed browsing) Specialized program requirement Activities that foster security concerns Task requiring computer saved information

When compared to handheld devices Tablets excel they're big screen displays and also more usable web browsers, mainly due to the screen display size. On the other hand Tablets suffer from some of the same hazards as mobile devices, which are (Seward, 2011b):

- Small font problems;
- Hover effects have a low performance;
- Clickability concerns;
- Extended scrolling difficulties;
- Data entry problems;
- Clickable icons size for fingers;
- Gestural effect's confusion.

These problems can vary from device to device, however they must be held into account when design applications.

Touch tables, walls, lecterns and kiosks

Touch tables are very similar to tablets devices as they are practically the same interface but in bigger size. As in tablets devices these tables have limitless applications whether industrial, medical or such other field of application. Such applications can be learning support, presentations, for storyboarding or brainstorming sessions (Technologies, 2012).
Considering Touchwall by Microsoft® this software allows many interaction possibilities, especially with smartphones. Touchwall by Microsoft® can recognize if a smartphone is place onto the touch surface and connect automatically to download photos, contacts or any other desired information. Some devices have also the possibility to use an appropriate stylus, which enables to sketch, design, brainstorm and mark documents as easily as with pen and paper. All this features can be performed with either hands or stylus without the need to toggle between input modes (Microsoft).

Touchscreen tables can come in various sizes and frames but serve the same purpose. For instance one can enhance client's interest with touch coffee tables that can be waterproof and high resistant glass to deal with lifetime weariness.

Touch walls use the same principle of touch tables but sometimes in a bigger scale and fitted vertically. For these types of touch devices frequently used controls are generally placed between waist and shoulder height to promote a practical touch experience (Tiresias, 2009). Some interfaces can be double tasking as they can be mounted as tables or touch walls as one can see in Figure 2.10.

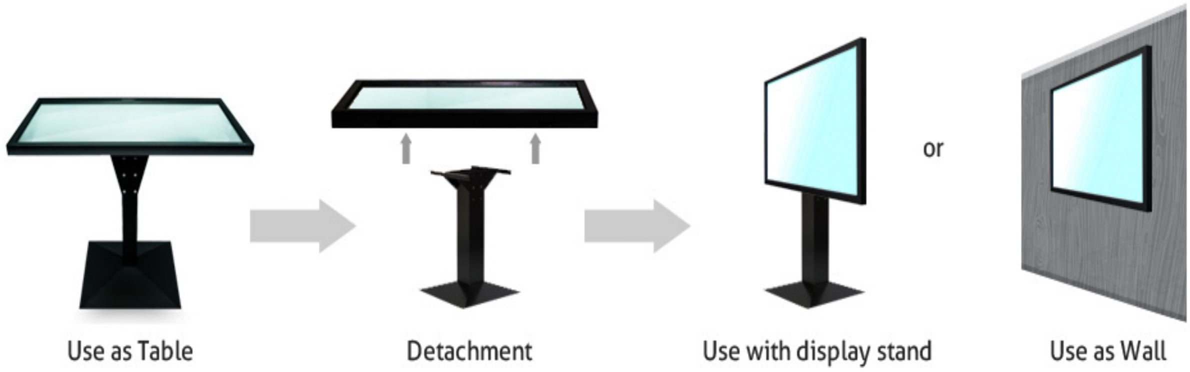

Figure 2.10 - Example of a Touch Table and Wall
***Retrieved from*: http://www.mymultitouch.de/wp-content/uploads/2012/07/modular_touchtable_illustration.jpg**

Touch lecterns are commonly used for presentations, where one can take notes or move between slides without turning your attention away from the audience.

Touch Kiosks are another variant from touch lecterns, normally used as ATM machines, airport check-in and also useful in public spaces as a way finder interface (Broz et al., 2012; Technologies, 2012).

These interfaces are very practical to deal with large amount of data, whether photographs or presentations or any other information. Also these interfaces as well as tablets are large enough to accommodate ten finger input, which increases data entry performance (Findlater et al., 2011). These technologies can be multi-touch which allows expanded gestures and even multiuser tasking. Multi user is very helpful for team work tasks and many other multi user applications (Microsoft, 2012).

Adequate viewing angle
Touchscreen viewing angle range in order to promote an adequate view of visual contents considering blur and light contrasts of the surrounding environment must be between 19 and 54.5 degrees off the horizontal and where the optimal would be a 30 degree angle, resulting in reduced fatigue (Beringer & Peterson, 1985; Sears ,1991; Schultz et al., 1998 *apud* HF Huang et al., 2007; Sears et. al., 1993).

2.4.3 Touchscreen Drawbacks

Concerning about drawbacks of this type of technology will provide more adequate touchscreen usability guidelines.
Touchscreen technology has some utilization drawbacks, mostly because of the lack of physical external inputs, such as, external mouse, joysticks or keyboards. Text entry is considered to be one of the major drawbacks of touchscreens (Findlater et al., 2011). Among these drawbacks

stands the lack of intrinsic haptic feedback, which unlike traditional keyboard inputs who provides contoured buttons and mechanical resistance of the keys in order to give the user positive feedback. This lack or keyboard may affect user's attention as they will need to look at the input keys to avoid pressing the wrong keys (Ryall et al., 2006 *apud* Findlater et al., 2011; Parikh & Esposito, 2012). These drawbacks are most exaggerated with small buttons, and many of the increased performance strategies (use of fingernails, stylus use, etc.) are only effective for resistive touch technology (Parikh & Esposito, 2012). Besides haptic feedback provides an enhanced experience with devices since it free user from having to focus on the input keys all the time, nevertheless frequent feedback may become and hindrance to performance, as users prefer selective and moderate haptic feedback (Leung et al., 2007; James & Brown, 1997 *apud* Parikh & Esposito, 2012). According to (Poupyres, 2004 *apud* Parikh & Esposito, 2012) users prefer typing on traditional keyboards than on touch screen devices, nevertheless positive haptic feedback increases typing performance when compared to touchscreen with no haptic feedback.

Touchscreens foster some ergonomic and usability drawbacks, such as, hand obstructing the screen, since screens serve as display and input devices. Manipulating these devices at eye level might be tiring for arm muscles, causing a condition known as "gorilla arm" (Wired, 2012 *apud* Parikh & Esposito, 2012). In addition, research shows that extended work focusing visual attention at table mounted or hand-held screens can result in neck fatigue (Langford, 1994 *apud* Parikh & Esposito, 2012).

Even though ergonomic issues may rise with extended use, they are more likely to become unnoticed in brief duration tasks.

Users normally send and receive more text messages than cell phone calls, and whilst typing they adopt unnatural postures. Using thumbs to type is an unnatural posture; therefore it poses ergonomic concerns with the extended use and without adequate breaks for thumbs to rest. This extended use, causes pain in thumbs and wrist muscles. Repetitive tasks imposed by text typing are not meant to be performed by thumb typing, especially in small areas (OSEH, 2010).

Ergonomic guidelines for mobile devices

Based on (Saffer, 2009) in order to avoid discomfort whilst using mobile devices some tips can be followed:

- Reduce keystrokes to avoid repetition by texting brief messages;
- Take advantage of word prediction and auto complete tools;
- Devices with full keyboards reduce keystrokes;
- Use shortcuts, they will decrease the need to scroll;
- Adopt a neutral wrist position whilst holding the device;
- Avoid bending down your head, adopt an upright posture;
- Relax muscles and avoid positions that cause hyperextensions;
- Use alternative fingers to reduce thumbs exposition and avoid static positions;

- Use the device in portrait position (see Figure 2.11) to reduce the reaching space thumbs will have to perform to hit keys.

Figure 2.11 - Example of a correct device typing position
***Retrieved from*: (OSEH, 2010)**

These principles can help developers to properly adapt gestures to touchscreen use. Therefore these principles provide bases and foster ergonomic constraints in touchscreen use, to create suited touchscreen usability guidelines.

Useful iPad development tips

Based on (Browne, 2011) one can highlight some iPad application development tips:

- Users view iPad devices as a small computer rather than a big smartphone. Therefore their applications should replicate computer's performance the best as possible. Should provide a fast, intuitive, full-featured experience and provide a fun experience;
- Users expect a full version of websites and a complete experience of the same;
- iPad devices serve commonly as a shared device which fosters security concerns. One must be assured to consider how use cases may be affected by multiple sharing.

2.5 Game Development

Game development techniques, such as, programing methodologies, design and graphical information and even key button locations will provided the knowledge necessary to establish usability guidelines better adapted to touchscreen mobile game applications.

2.5.1 Game Testing

There are many requirements for game testing guidelines and criteria to evaluate. In order to satisfy publishers, clients and users, game applications should be tested throughout a well-defined methodology. The contrary will result in defective games, with no usability, resulting in a lack of user satisfaction. In a simple way, testing must aim to identify and solve structural and usability problems with the game (Reddy, 2008).

There are two main forms of game testing:

"**Clear Box**" or "**White Box**" focus on the architecture and integration aspects of the software (e.g., interaction with rendering engine). For this type, testers must understand more internal aspects of the application, such as, coding (Reddy, 2008).

"**Black Box**" focuses on functionality and usability aspects of the game. For example, testers will analyze gameplay, the use of buttons, graphics and animations, overall consistency and so on. This type of testing is more adequate for usability testing since it focus on the actual purpose of the game (to play it) than on structural issues (coding). For this type testers must know how to play the game (e.g., game rules, game functions) (Reddy, 2008).

Game testing is not meant to be performed through a single's person work, but instead the responsibility should be spread evenly through the work team responsible for the development of the game. Each person should instill the quality of work and contribute with accuracy and commitment to produce a more quality and usable game. For these reasons, testing should not be used in isolation, and should be a part of a fully structured production process. As part of the testing process testers must acknowledge all testing requirements, in order to establish what does need to be tested and what does not, leaving further specialized details for designers and developers. Being that, a requirements' document must be created, such as, track list or an extended checklist. This document should aim to include the most details possible, regarding that major game functionalities are assured to be tested (Reddy, 2008).

According to (Reddy, 2008) one can quote some testing techniques and tips:

- Test for inappropriate collisions between objects (e.g., cars collisions);
- Test for loading and saving messages and assure the correct messages are displayed;
- Ensure loading time is within acceptable terms (no more than 20 seconds);
- Look for delays or micro-pauses that even though the game does not stop they might affect overall gameplay;
- Test game end of bound. The game should not allow the character to go beyond that end of bound;
- Make sure that every time you get a new build you have all files needed;
- Make regression tests, and check for previous bugs. Even though some bugs might be fixed in previous versions it does not mean that they might still work in the current version.

2.5.2 Hover Effects

Hover effects are very commonly used in UI and increase aesthetics as well as usability. These effects allow users to have a positive feedback about their actions, and know for example which button or key they are selecting. Especially for touchscreen devices where normally there are no physical elements that indicate click location, such as, mouse arrows, one needs to be acquainted with the input selection location. Therefore hover effects are very effective in this matter. Hover effects allow the possibility to acknowledge which buttons are clickable or not. For example, considering touchscreen mobile devices, hover effects allow the button to change color, size, shape or many other features once is selected, giving the user the feedback that the button is clickable, as further showed in Figure 2.12 an example of a dynamic concave effect that shows up once the button is selected giving the user the appearance that the button is selected and increases usability (Hsinfu Huang & Lai, 2008).

Figure 2.12- Example of a 3D concave button hover effect
***Retrieved from*: http://uxmovement.com/buttons/using-gradients-on-buttons-correctly/**

Giving feedback for users actions is very important, especially when dealing with new interfaces. The user sometimes faces itself with non-explicative buttons that a user does not know which action or function the button represents. Regarding mobile applications where user satisfaction is a critical element, this function might come as an increase of users' satisfaction. For this purpose hover effects could include a button label that explains the button itself and its consequence.
An example of a hover effect that illustrates this can be viewed in Figure 2.13.

Hover effects have many applications, but are known for their aesthetic and usability advantages. Whether changing color, adding a label, increase color gradient or shape, these tools are very often used in the software creation field.

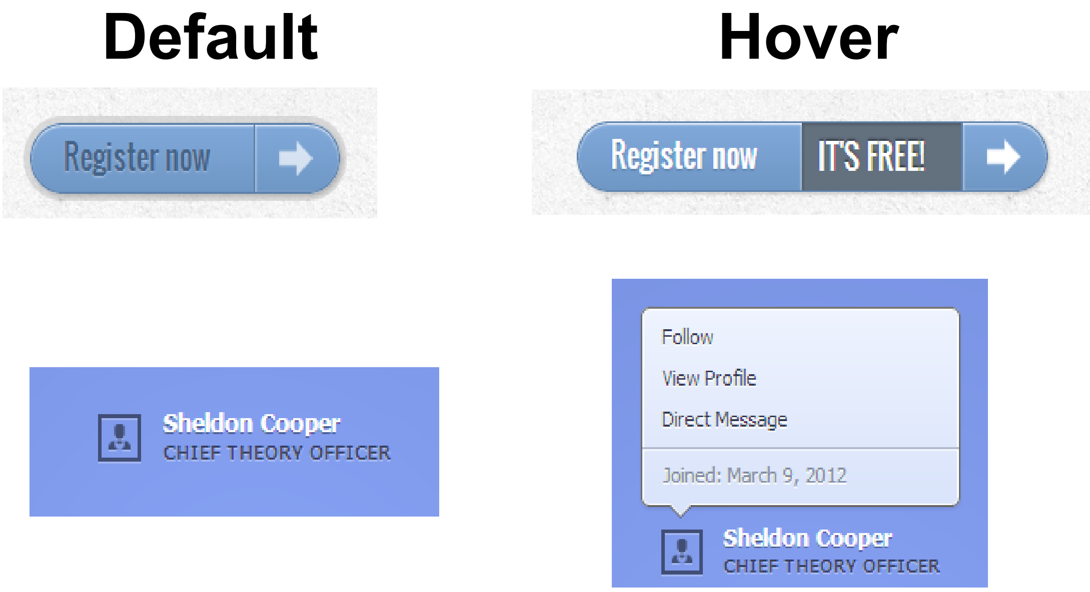

Figure 2.13 - Examples of Labeled Hover Effects
***Retrieved from*: http://demo.webinterfacelab.com/13-profile-popover/; http://tympanus.net/Tutorials/AnimatedButtons/index4.html**

2.5.3 Key Size, Spacing, Location and Response Time

Key size on touchscreen technology is a largely influent characteristic in usability and one of the most important design factors (Pfauth and Priest, 1981 *apud* Park & Han, 2010). It can increase or decrease reaction time which can represent serious consequences, if for example when applied in firefighting combat or health industry.

According to (Colle & Hiszem, 2004) relatively to touchscreen key sizes regarding usability concerns a 20 mm key size is sufficient. If touchscreen space is less than 20mm (17-18mm) it can be as usable as well but never opt for 15mm as this may foster usability issues. A study conducted by (Jin, Plocher, & Kiff, 2007) revealed that Older adults preferred mostly large, but not too large, key sizes, somewhere between 16,51mm and 19,05mm square. Also predictable is the decrease in the reaction time and number of errors as button size increases. (Sun, Plocher, & Qu, 2007) report in their study of the smallest comfortable button size on touch screens, that most correct answers were related to key size equal or bigger than 40x40 pixels (aprox. 10,6x10,6 mm). The previous data can corroborate the information mentioned by (Park & Han, 2010) in the table 3 of their study, that reveals that for small touchscreens the best key size would be 10mm and that for bigger screens one can implement 20mm key size. It is also worth mentioning that for stylus use it is recommended a key size of at least 5x5mm (Lee & Kuo, 2004 *apud* Lee & Kuo, 2007). Relatively to small key sizes commonly used on mobile devices, resistive touch technology, which work by pressure, is more suitable for small buttons (Parikh & Esposito, 2012).

Different aspects influence key size decision: screen size; Interaction type (one-handed, two-handed); Fingers size; distance between users and the touchscreen.

Key spacing can be influential in usability even though is not as critical as key size or location. If touch screen size is not a limitation one may implement a 1mm edge-to-edge space between buttons. Regarding spacing characteristics one may be lead to assume that larger spacing is associated with increased usability, but is false, it must be adapted accordingly. For instance according to (Colle & Hiszem, 2004) for 20 mm key sizes, a 10 mm space edge-to-edge degrades performance. Therefore large spacing will increase reaction time and degrade performance. If in other hand touch screen space is a limitation and key size may also so be affected, one may implement zero spacing (Colle & Hiszem, 2004; Jin et al., 2007).

Key location has been considered as an important factor that can affect usability of touchscreen devices. A study developed by (Park & Han, 2010) regarding one-handed thumb touchscreen interactions revealed many important information on key location in touchscreen mobile devices. Left areas of the screen represent a good placement for small touch keys whilst the center and right areas tend to be good for bigger touch keys, such as, 7 or 10mm. Regarding effectiveness, the area that is related to fewer errors is the left area of the screen. In this part of the screen keys are less hided by the hand when performing tasks, and represents a good area for accurate controls displacement. Taking into account right-handed people lower right areas represent low usability areas since they are interfered by the right hand, the inverse applies to left-handed people. Moreover in the uppermost and lowermost areas no touch keys should be applied, taking into account lower satisfaction levels and pressing performance in these areas. In addition frequently used touch keys should be placed in the central area of the screen whenever possible (Park & Han, 2010).

During task execution button size represents a direct influence in touch usability characteristics whereas button spacing has not an influential relation (Sesto, Irwin, Chen, Chourasia, & Wiegmann, 2012). Middle-aged and elderly targets have more difficulties with perception than younger public. In addition normal younger adults can have a working memory able to memorize up to 7 criteria whereas elderly adults may be able to memorize 5 criteria (Schieber, 2003, p 64 *apud* Lee & Kuo, 2007).

Response Time affects user performance as well as their satisfaction. Therefore it is of extreme importance to implement the adequate response time upon users' clicks. According to (Shneiderman, 1984) there are three main factors that can influence the response time user expectations:

1. User expectations due to previous experiences;
2. Variations in users and tasks may affect adequate response time;
3. People are able to adapt to such response time however their performance and satisfaction are likely to suffer.

Therefore implementing the correct response time in each button will depend upon the tasks itself, the game application, the users, but it is preferable to implement a response time of 1 second or less (Shneiderman, 1984).

2.5.4 Color Blindness Issues

Color vision deficiency (Color blindness) is a congenital and inherited disorder. It affects approximately 8% of males and 0.5% of female population. Normal people are trichromatic, and they can visualize any color by a mixture of three wisely chosen primary colors. There are three classes of cone photoreceptor in the human eye, short-wavelength or blue sensitive, medium-wavelength or green sensitive, and long-wavelength or red sensitive. Each and only can determine the rate at which light is absorbed. Consequently one cone alone cannot convey information about wavelength. The visual system in order to establish color vision compares three signal responses (Simunovic, 2010).

Types of color blindness

There are different classes of color blindness, starting from the mildest to the severest we have anomalous trichromacy, dichromacy and monochromacy (Simunovic, 2010).

Anomalous trichromatics also require three primary colors to match any other color. Nevertheless the way they mix the primary colors might be abnormal. It is subdivided into, protanomaly (that affects red cones), deuteranomaly(that affects green cones), and tritanomaly (that affects the blue cones). In some situations trichromatics may have an advantage since they can accept color matches that a normal retina cannot, and so for that reason can be an advantage for breaking camouflage which can be useful for military purposes (Simunovic, 2010). Dichromacy is the second severest form of color-blindness it affects one of the three cones and therefore dichromats require two primary colors to match any other colors. It can also be subdivided into 3 groups, protanopia (lack of functional red cones), deuteranopia (lack of green cones), and tritanopia (lack of functional blue cones) (Simunovic, 2010).

Finally the severest form of color-blind deficiency is Monochromacy. In this deficiency there is no color discrimination. Monochromacy can be subdivided into rod monochromacy, blue, green and red-cone monochromacy. Rod-chromacy affects the cones to the point where they are completely dysfunctional or non-functional, therefore visual function is dominated by rods (mainly used for night vision in a normal retina). The three other types of monochrocamy, whether green red or blue, are characteristic for having only one functional cone. For instance, considering the blue-cone chromacy, in this deficiency the only functional cone is the blue one whereas the green and red are non-functional (Simunovic, 2010).

Even though there are different types of color-blindness the most prevalent type in humans is red-green color vision deficiency. This term includes protanomaly, deuteranomaly, protanopia and deuteranopia, usually referred to red and green cones, all of which are X-linked recessive vision deficiencies (Jenny & Kelso, 2007; Simunovic, 2010). Europeans are considered to have the highest prevalent rate whereas Africans have the lowest (Delpero WT, O'Neill H, Casson E, Hovis J, 2005 *apud* Simunovic, 2010).

Color vision deficiency is a serious disadvantage when performing visual tasks. Especially in game applications where users are required to match colors, this deficiency can come as a hindrance. Consider car signal lights, those with protanopia and protanomaly might have an increased risk of having rear-ended collisions (Cole BL, 2002 apudSimunovic, 2010). In game applications there is a large range of color information and it is very important for users the appropriate color recognition in order to an adequate gameplay. Regardless of the environment colors are of great importance for detection and identification of objects, for information purposes and for the aesthetic point of view.

As an outstanding form of helping color-blind people in color recognition, is the ColorADD® system code. ColorADD® is a color identification system used for color-blind people, which can be useful in many lifestyle tasks, whether clothe choosing or performing simple match color tasks. With the ColorADD® system codes are used to translate colors into shapes, as one can see in the following Figure 2.14. These shapes can be included into icons to allow users to recognize color and easily play the desired game applications.

Figure 2.14 - ColorADD® code system
***Retrieved from:* (Neiva, 2010)**

CHAPTER 3 - METHODOLOGY

In this chapter it will be described the methodologies used during this study. First it will be addressed the Dissertation methodology which will explain the basic outputs of this study throughout its completion. Secondly it will be shown the methodology used to create the UsaGame checklist. This second methodology is more explicit and aims to elucidate the basic steps of the UsaGame development process.

3.1 Dissertation Methodology

The literature review background, touchscreen mobile game application tests, the specific beta users' report, provided by the game development company and all the empirical knowledge obtained provided the means necessary to adapt previous guidelines and establish new ones for touchscreen mobile game applications usability. The implementation of those guidelines into the UsaGame was performed throughout a second game test (Game Test 2), to a different game application still in development, and a partnership with a specialized game applications development company. The checklist aims to support usability evaluation in touchscreen mobile game application development process, and therefore fosters the need for its validation which was later made by a usability evaluation test. Figure 3.1 shows the methodology that was applied in this study as well as is outputs.

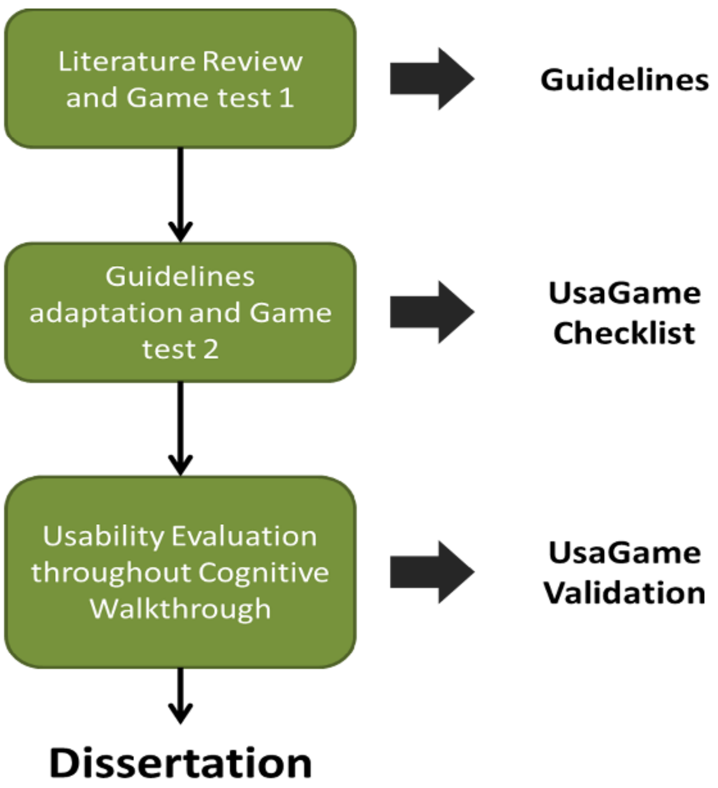

Figure 3.1 - Dissertation Outputs' Methodology

The checklist validation process was carried out through a usability evaluation procedure with a Cognitive Walkthrough Protocol (CWP) that was built for the assessment of the usability guidelines implemented into the Megaramp game application.

3.2 Methodology for UsaGame Checklist Development

In order to accomplish the objective of creating a Usability evaluation support checklist for game applications, a more specific methodology was followed.
In the interest of UsaGame development the author worked with a specialized game applications company named Biodroid. Biodroid is an entertainment company that builds game applications for mobile devices and other platforms such as, Nintendo DS, Nintendo Wii, Facebook, PC/MAC, being those of the interest of this study the following touchscreens with either iOS system or Android. For this purpose the author worked side by side with designers and application developers following two game applications in order to create suitable guidelines for touch mobile game applications. For these two game applications I used the iPad mobile device. Even though both iPhone and iPad have similar software systems they differ in the screen size which can significantly affect usability evaluation. Therefore my observations were made for the iPad device; nevertheless they can be applied and adapted to other touchscreen mobile devices.

The checklist development process is based upon 3 pillars further divided into theoretical and practical fields. First related to a theoretical background, Literature Review provided the bases necessary for this study development. Many studies and heuristics have been created regarding usability issues, but their main purpose was to serve for desktop computers and their use. With new technologies flourishing new usability issues arise and therefore the need to adapt or create new heuristics for these technologies is required. Regarding these factors the checklist serves a specific purpose since it is based on previous usability heuristics and previous studies (Inostroza et al., 2012; Ji et al., 2006; Nielsen, 2005) it is designed for touchscreens mobile devices. Nevertheless it can be adapted to other touchscreen applications rather that only game applications. Literature Review allowed me to perform a better assessment of usability of interfaces, and to outcome with a list of usability guidelines better adapted to touchscreen mobile game applications.

Secondly Game test 1 and Excel sheet information are the two remaining groups related to a more practical background. Game test 1 was a usability test performed by the author to get acquaintance of usability problems as well as game functionalities. This Game test serves contributed for the empirical knowledge gathered to the adaptation of previous desktop guidelines to touchscreen game applications. The excel sheet that was shared by Biodroid, contained information about previous tests performed by beta users to the first application, Billabong Surf Trip (BST). The methodology that was followed can be better understood in Figure 3.2.

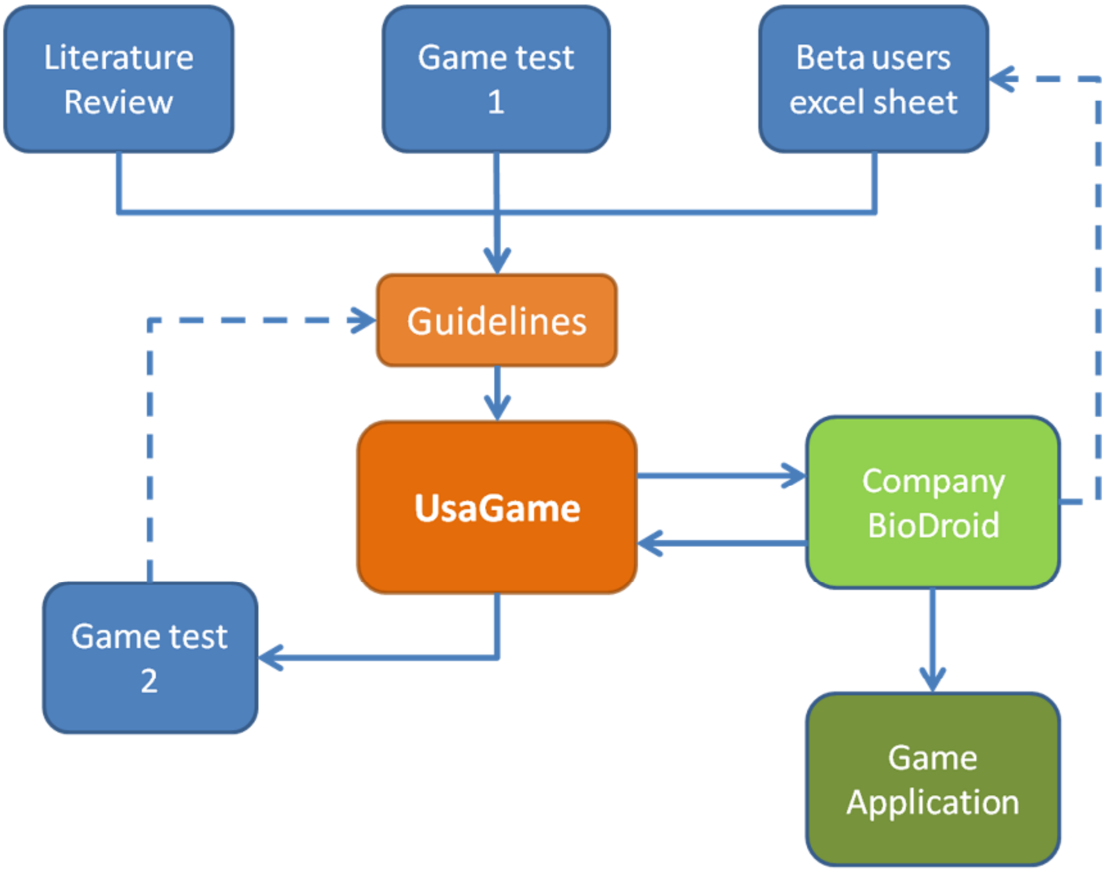

Figure 3.2 - UsaGame Checklist Development Methodology

Game test 2 was performed in a second game application that was still in its development process (Megaramp). This test was carried out with the company's assessment. The continuous feedback of the checklist development and the game usability problems found throughout the different stages (Builds) of the game provided the means necessary to an updated checklist to support the usability problems founds. In addition these flows of information became important to understand which factors were and were not relevant for Game application's usability.

CHAPTER 4 - USAGAME DEVELOPMENT AND TEST

Throughout this chapter the main outputs of this study will be addressed. It will be explained the initial tests made to a fully functional game application (BST). The test made to the Megaramp application will also be explained, as well as the usability problems that derivate from those tests. Furthermore it will be shown the usability touch screen game application guidelines. Finally it will be explained the usability evaluation test made to assess the UsaGame validation.

4.1 Game Testing – Results

Game testing was performed using the UsaGame (Annex 1) and regarding all the previous literature review background. To increase UsaGame credibility a hybrid method was adopted withstanding heuristics short comes that will be mentioned next. For these sets of game testing the iPad device was used in an office environment with reliable wireless connection and adequate test conditions, such as, adequate light and sound conditions that allowed users to fully concentrate on the test. These tests were conducted through normal game utilization performing different tasks and exploring the most out of each game application.

Heuristics may not come across all usability issues during a game testing evaluation, and their interpretation may vary from situation to situation, as in game to game. Heuristics effectiveness may not be fully practical, as they may not encounter all issues in game applications and also induce game tester that issues that are not found in the evaluation may not be found by users. Therefore the most effective method to uncover usability issues in game applications should be a hybrid approach performing heuristic evaluations and usability testing.

4.1.1 Game test 1 – Billabong Surf Trip

The first application, Billabong Surf Trip (BST), was provided by Biodroid and it was already developed which allowed me to acknowledge some basic game applications features and also understand and report some malfunctions and usability issues. BST is a fully functional surf game that is already in the market. The game allows users to execute surf maneuver through touch inputs. This test consisted on playing the application to understand its gameplay and with a more objective goal of finding possible usability problems. It was performed different tests in order to acknowledge the more usable problems and concerns as possible, and also acquire knowledge about basic usability functionalities of game applications.

Even though it was a fully functional game application, some notes were gathered that foster some usability concerns.

Icon design – For a good delineation and better understanding of icons, bold lettering could be supported.

Icon Label – In order to increase usability some hover effects should be adopted, such as different color gradients when an icon is selected, and also labels should be available in some icons so users can easily predict what happens upon clicking.

Practical tutorial – In this game in particular there is no background tutorial and the extensive tutorial is divided into information about the surf area and simple tutorial information. In this game there were some tutorials that do not had skip function which can cause users boredom as one can see in Figure 4.1.

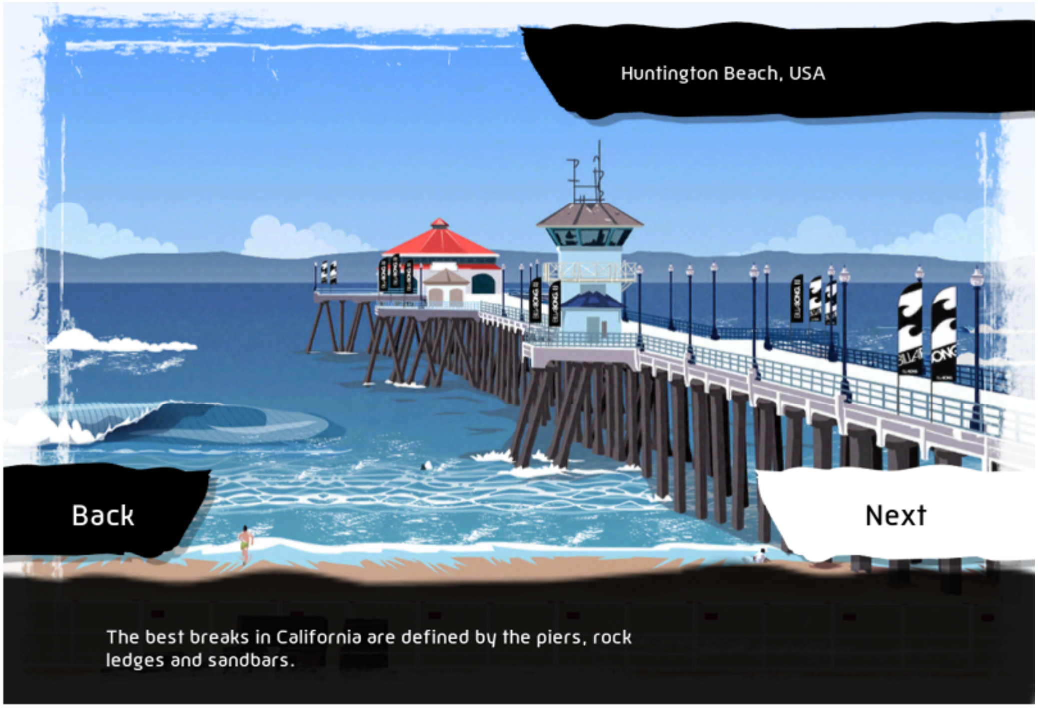

Figure 4.1 - An example of a non-skipped tutorial

Use appropriate touch actions – In BST there is no release response touch action which may affect users choice, since once the user has selected some feature it cannot change its selection. Also there are some cases of excessive click activity, such as, foot orientation selection that one has to click to select and then click again to confirm, which may decrease the buttons usability. Also when the game ends and players want to play again, the retry again button appears far from user's normal clickable area. Also the buttons that is in the lower right corner is the menu icon which leads users to accidently click in the main menu button instead of the retry button, this can be better understand in the following Figure 4.2.

Support touch gestures – When selecting some functions, touch gestures are confusing, such as selecting hair style and sex, that the user has no intuitive perception of how to choose between those options.

Memorize players options – The type of foot orientation whether left foot front or right foot front is not well specified (Regular or goofy).

Figure 4.2 - An example of poor criteria localization

This test provided knowledge about interface limitations. Mobile devices do not always support the optimal graphic resolution, since they are not always free to configure, the user is left with the standard presets, which can affect overall speed and gameplay in some devices. Some interfaces pose some hindrances to designers and developers as they have to follow some regulations in order to have their game application available for that type of interface. For example, consider iOS systems, they do not require an exit game button since this is performed by the main button of the interface. This limitation can be seen as an optimization feature and quite handy since the user can exit game with such easiness, but in other hand when the user wants to enter the game again, the application will star from the beginning leaving no possibility for the user to pause the game.

4.1.2 Case study – Game test 2

This case study was performed by testing and analyzing an upcoming game application (Megaramp), provided by Biodroid. The test consisted in a series of tasks aiming to explore the most out of the game application. The UsaGame was used as a usability evaluation support to note and report possible usability problems and become aware of others that were not yet included. This game test process was performed with the assessment of Biodroid so both parties could be acquaintance of possible usability problems and could discuss the UsaGame process and its relevant factors. Every game stage (build) was tested as soon as it was made available by the company for appropriate testing and resulted in a specific Build usability problems' report. This report allowed the company to get acquaintance and solve usability problems.

1st Megaramp Game Stage (Build 1.0#27)

Starting on the first build available (Build 1.0 #27) the game application was submitted to different tests and the resulting Usability Evaluation Checklist report origin the following usability remarks and an usability tip showed as a viable solution:

Play screen features: There is no explanation of some functions that are displayed in the play screen.
Usability Tip – Implement labels on those functions so users can acknowledge them; this can be visualized in Figure 4.3 by the red circles.

Practical Tutorials: Background tutorials where adopted, which increase users gameplay and decreases user's boredom, but nevertheless they are incomplete and do not appear always, leaving the user disoriented. Also the hold tutorial appears in the pause menu.
Usability Tip – Allow the user to choose if whether or not they want the tutorials to appear; an example of the practical backgrounds adopted can be visualized in Figure 4.3 in the center area, as a finger tutorial.

Button Location in portrait mode: When performing the "jump" maneuver the user is asked to perform a slide action in a descendent movement. Such action poses some usability when dealing with the device in portrait mode with the main button facing down, since the user accidentally clicks the main button, leaving the game as being forced to start all over again. **Usability Tip** – Implement a more intuitive maneuver by sliding upwards. This will also solve the accidental clicks to the main button, and increase usability; this example can be visualized in Figure 4.3.

Figure 4.3 shows the screen play view where two sidebars, one on each side, are showed but are not explained in terms of their functionality. Furthermore the arrow in blue represent the finger movement the user is required to perform which can lead to accidental clicks to the main button.

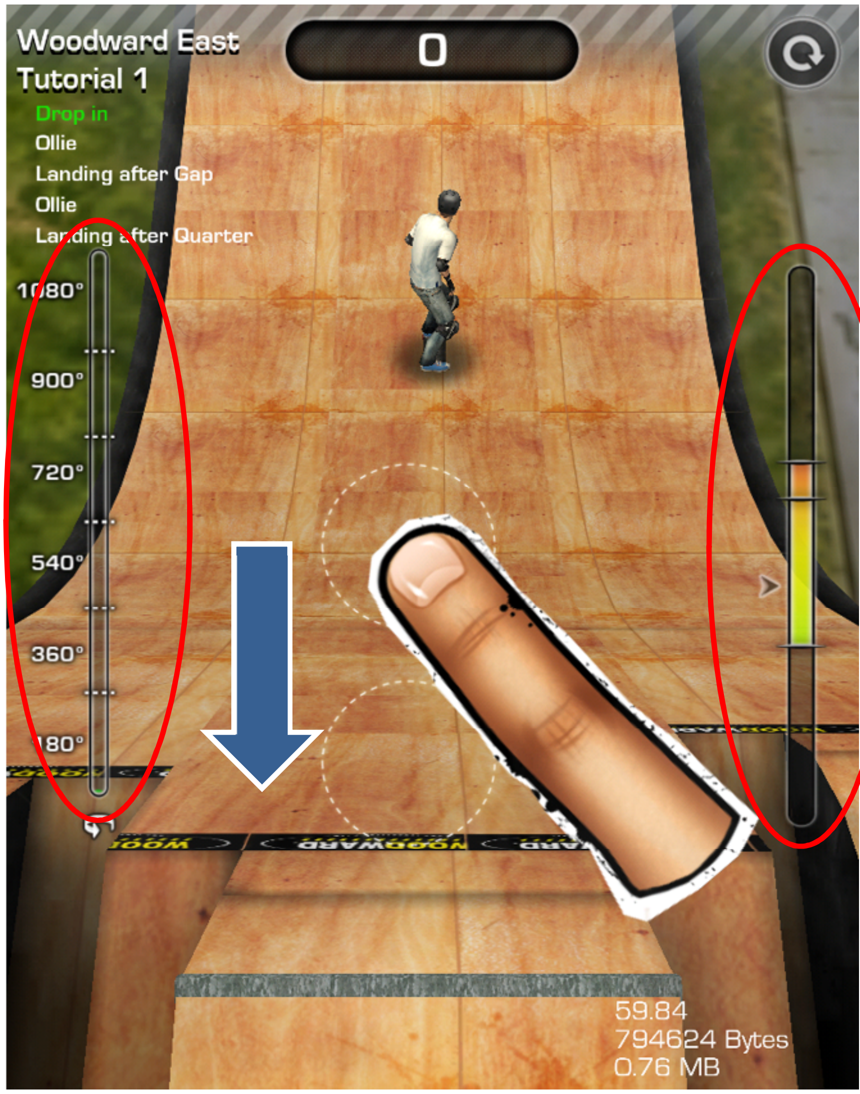

Figure 4.3 - Screen play view in Megaramp Build #27

Gameplay: Background tutorial induces users to use their index fingers to play. This strategy poses some difficulties when holding the device.

Usability Tip – Induce the users to play with thumbs, this will give a more natural gameplay whilst holding the device.

Proper feedback given: Some buttons do not provide the proper feedback if either they were clicked or not.

Usability Tip – Implement hover effects, such as, concave shapes or sound effects to give proper feedback and so buttons can appear clicked to users.

Different Feedback means: Throughout the game application there is no audio or tactile feedback that warns users about their actions. This misleads users to think their actions have not been executed.

Usability Tip – Implement proper audio or tactile feedback without obstructing user's focus and gameplay.

Use appropriate touch actions: Despite some buttons have an adequate response time some others have an extended response time (more than 3 seconds) or lack of feedback which leads users to click again and again to reassure their actions.

Usability Tip – Implement adequate response time in every click or give the user proper feedback of their actions by implementing hover effects that show the users that buttons have been clicked.

Icon design: Some buttons do not appear clickable, leaving the user with incomplete information about the game features, such as, the mode button (red circle in Figure 4.4), where the user can choose between skate and Bmx. Also the sex exchange button does not appear. **Usability Tip** – Apply dynamic effects and hover effects so buttons can appear clickable to the user.

Figure 4.4 - Customization menu view in Megaramp Build #27

Figure 4.4 shows the customization menu where some usability problems relatively to icon's static movement become relevant. In the lower right corner it is displayed the mode button, that alternates between skate and Bmx mode. This button has a static movement which can mislead users whether or not it is a clickable button.

Player's options: When in play mode the player's clothes differ from the ones the user as previously chosen.

Usability Tip – memorize users' options.

Language Support: This build does not include language support whatsoever.
Usability Tip – Implement main language support in the next build versions.

Portrayal of real life: In skate mode when the player crashes, the skate continues moving sideways without stopping even if the retry menu appears.
Usability Tip – Implement more realistic consequences or when player crashes stop the game and display the retry again menu.

2nd Megaramp Game Stage (Build 1.0#28)

The second game analysis was made to build 1.0#28, a more developed build and was expected to overcome some of the previous usability problems found before and therefore to have an increased usability. Even though, some of the previous usability problems were not yet solved the following analysis was made containing some remaining usability problems and improvements.

Remaining usability problems

Play screen features: There is still no explanation of play screen side bars.
Usability Tip – Implement labels on those functions so users can acknowledge them.

Icon design: Static button movement problem still remains and buttons do not appear clickable for users. Also the sex change button still remains missing.
Usability Tip – Apply dynamic effects and hover effects so buttons can appear clickable to users.

Practical tutorial: Tutorials inconsistency is still present. The hold tutorial is still displayed in the pause (retry) menu.
Usability Tip - Allow the user to choose if whether or not they want the tutorials to appear.

Use appropriate touch actions: Some buttons still exceed the adequate response time leading users to click buttons again and again.
Usability Tip – Implement adequate response time in every click or give the user proper feedback of their actions by implementing hover effects that show the users that buttons have been clicked.

Gameplay: Background tutorials still induce users to play with index fingers.
Usability Tip - Induce the users to play with thumbs, this will give a more natural gameplay whilst holding the device; this problem can be viewed in Figure 4.5.

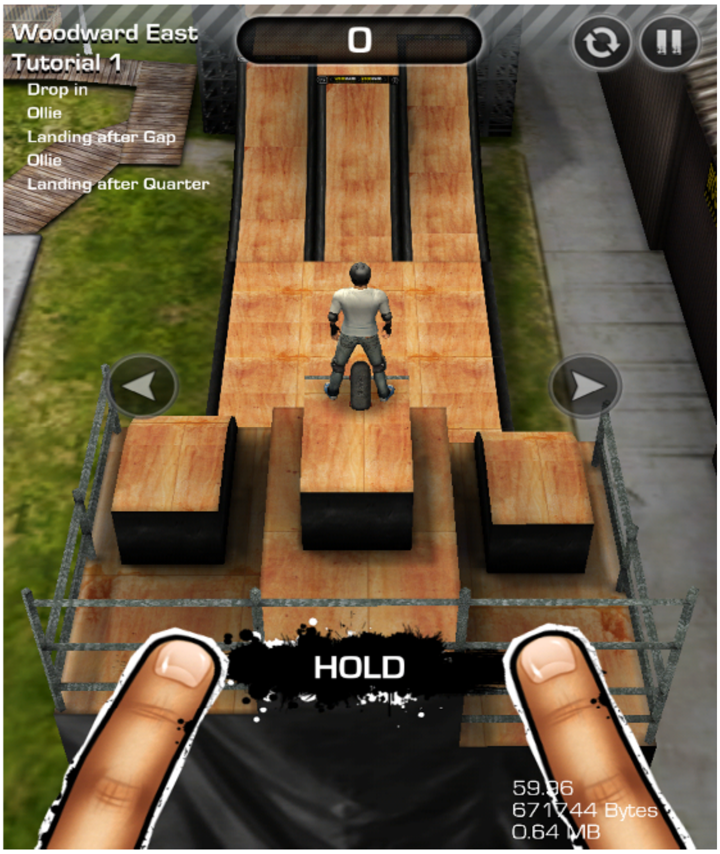

Figure 4.5 – Game play screenshot in Megaramp build 1.0#28

Proper feedback given: Some buttons do not give user the proper feedback if either they were clicked or not. Consider for example in Figure 4.6 in the main menu the mode button, to exchange between Skate and Bmx mode, does not outstand properly due to its static movement.

Usability Tip - Implement hover effects, such as, concave shapes or sound effects to give proper feedback and also buttons can appear clickable to users.

Use different feedback means: There is still no audio or tactile feedback support. This can decrease user's interactivity with the game application.

Usability Tip - Implement proper audio or tactile feedback without obstructing user's focus and gameplay, such as, music change upon entering the play mode, this will give a more precise feedback to the user that the game interaction will start.

Player's option: Player clothes still differ between user's customization and the ones that appear in play mode.

Usability Tip - Memorize users' options.

Figure 4.6 - Main Menu in Megaramp build 1.0#28

Portrayal of real life: In skate mode, when the player crashes, skate movements still do not fulfill real life expectations.
Usability Tip - Implement more realistic consequences or when player crashes stop the game movement and display the pause (retry) menu.

Improvements

In this build some of the main menu functions now work properly in relation to the previous build, such as, game data menu, where main language and game achievements are displayed.

Language: It is now available main language support (Portuguese and English) that one can exchange accordingly to one's preference. Even though this option is available it is not yet fully developed since it does not change the game language, predefined in English. This can be visualized in the game data menu as shown in Figure 4.7 highlighted in the red circle.

Design of multiple users: According to (Simunovic, 2010), one should avoid the use of Red and Green colors in critical decision tasks, and if so, implement user known shapes. This is example can be showed in Figure 4.8 and noticed that the use of check mark and cross eases the decision making process and at the same time increases its adaptability for color-blinds.

Figure 4.7 - Game data menu with language function on Megaramp build 1.0#28

Figure 4.8 - Example of user-known shape implementation in Megaramp build 1.0#28

Button location in portrait mode: The previous build (#27) had a usability problem with the "jump" maneuver that was performed through a downwards slide movement. This caused users to accidentally click the main button of the device, leaving the game. In this build this was solved changing the slide movement orientation from downwards to upwards. This exchange increased the maneuver's intuitiveness and also is less able for users to accidentally click the main button.

3rd Megaramp Game stage (Build 1.0#30)

This third build (1.0#30) has a more developed menu structure, where all menu features work even though with minor problems. This Build shares a more accurate relation with the final game application and results in some usability improvements. Nevertheless this build still has some usability problems to overcome, some of them resulting from previous analysis.

Remaining usability problems

Play screen features: In the play screen, side bars still do not have any label to inform users about their usefulness.
Usability Tip - Implement labels on those functions so users can acknowledge them.

Navigation Features: The Trickology menu is now available and displays a list of possible tricks. This list does not have any side bars to inform users about its length and keep users tracked about their position in the list. In addition side bars are useful to easily navigate to the bottom and top of lists.
Usability Tip – Implement side bars on lists so users can travel from top to bottom and acknowledge their overall position in the list. The list shown in Trickology menu can be visualized in Figure 4.9.

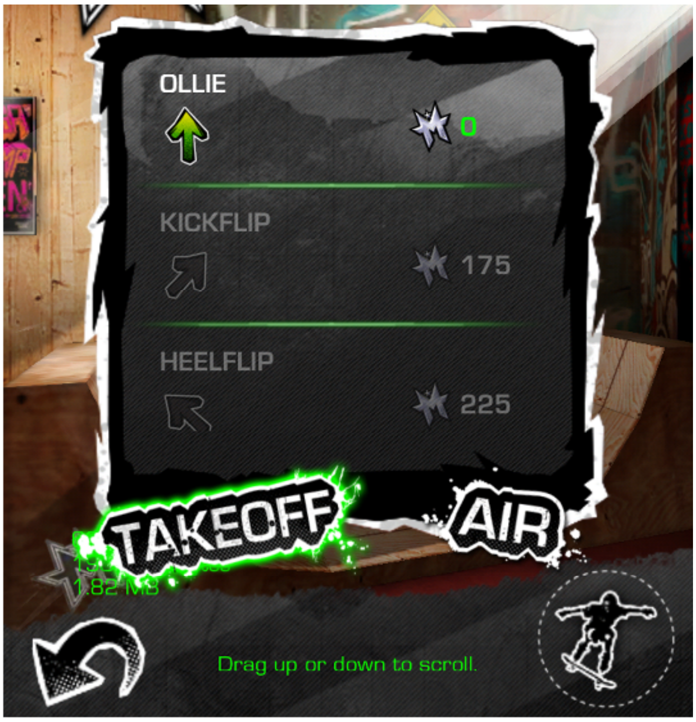

Figure 4.9 - Partial View of the Trickology menu in Megaramp build 1.0#30

Icon Design: Static icons still pose some challenges for users to acknowledge their click ability, such as, the sex button (red circle) in Figure 4.10 that becomes unnoticed.
Usability Tip - Apply dynamic effects and hover effects so buttons can appear clickable to the user.

Practical tutorials: Tutorials are still not fully functional. Some background tutorials are not displayed accordingly to their actions. In addition hold tutorial is still displayed in the pause menu.
Usability Tip - Allow customization for users to choose if whether or not they want the tutorials to be displayed.

Use appropriate touch actions: Some buttons still exceed the adequate response time leading users to click buttons repetitively.
Usability Tip – Implement adequate response time in every click or give the user proper feedback of their actions by implementing hover effects that shows the user that buttons have been clicked.

Figure 4.10 - Character selection Screen in Megaramp 1.0#30

Provide proper feedback: Some buttons do not provide users the proper feedback if either they were clicked or not.

Usability Tip - Implement hover effects, such as, concave shapes or sound effects to give proper feedback and also buttons can appear clickable to users; an example of poor feedback in buttons is present in the achievements menu that is shown after a trick completion phase. Figure 4.11 shows the achievement's menu that contemplates some buttons, such as, main menu, retry and next challenge that do not provide proper feedback once they are clicked.

Figure 4.11 - Achievements menu in Megaramp build 1.0#30

Use different feedback means: There still is no audio or tactile feedback support. This can decrease user's interactivity with the game application.

Usability Tip - Implement proper audio or tactile feedback without obstructing user's focus and gameplay, such as, music change upon entering in the play mode, this will give a more precise feedback to the user that the game interaction will start.

Player's option: Player clothes are still different between user's customization and the ones that appear in play mode.

Usability Tip - Memorize users' options.

Language: Main Language support problems still remain unsolved. The option is available but nevertheless it shows no trade between the predefined language and the one chosen.

Gameplay: This build as a bug in the Bmx mode, since one cannot play in Bmx mode. Even though in the customization menu one can customize all options related to Bmx mode.

Improvements

Gameplay: New tutorials now induce users to play with thumbs, which increases ease of interaction whilst holding the device. This example can be further showed by the thumb tutorials in the lower area of the Figure 4.12.

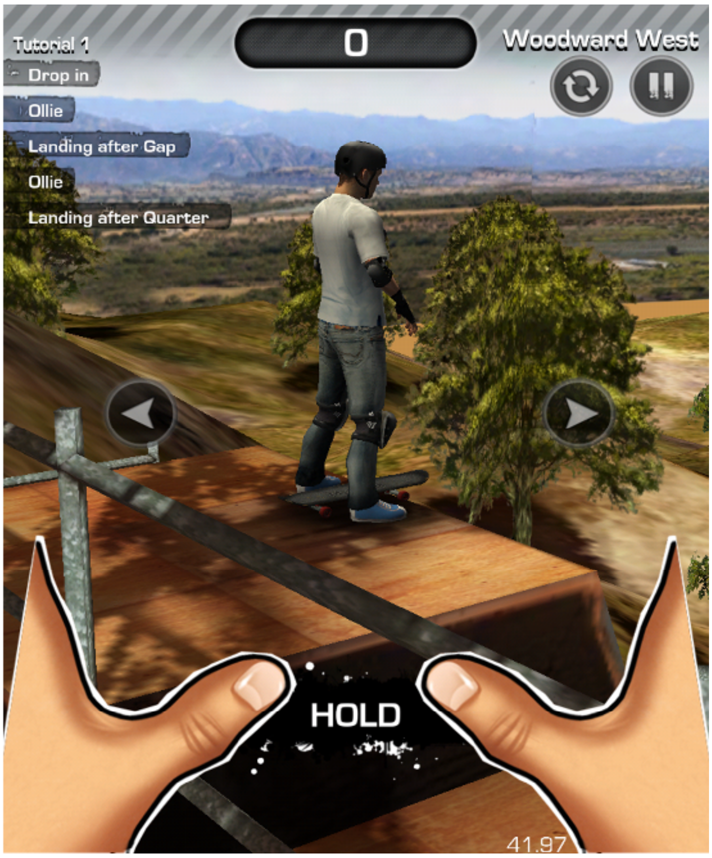

Figure 4.12 - Play screenshot in Megaramp build 1.0#30

Wireless connection: In this build Theater menu is now available, which displays video hyperlinks related to the game application. This wireless demand is made with the recourse to the device's internet browser, which does not affect directly the game application gameplay since these hyperlinks are uploaded externally from the game application. Nevertheless reliable wireless connection is advised. A partial view of theater menu hyperlinks can be seen in Figure 4.13.

Portrayal of real life: Skate's unreal crash movement problem is now solved and when the player crashes the game freezes and displays a pause menu.

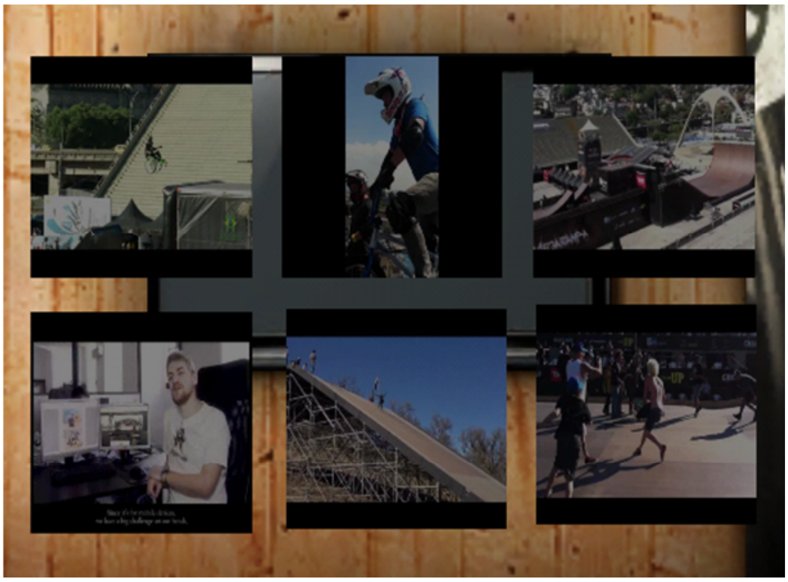

Figure 4.13 - Partial Theater menu view in Megaramp build 1.0#30

4th Megaramp Game stage – Final version 0.9

This last test was performed to the final version of the game application and it was the first version of the Megaramp application launched into the market. Being the final version it was expected to have few usability problems, nevertheless it still presents some usability drawbacks.

Usability Problems

Navigation: The return button in the Trickology menu within the pause menu is displayed in the main central area which may lead users to perform accidental clicks whilst navigating through the list. In Figure 4.14 the red circle highlights the previous problem.
Usability Tip – Locate the return button in one of the lower device corners to avoid accidental clicks.

Navigation Features: In the Trickology menu there is still no side bar in tricks list. This difficulties user's interaction and decreases this menu usability.
Usability Tip - Implement side bars on list so users can travel from top to bottom and acknowledge their overall position in the list.

Icon Design: Some icons still have a static movement which difficulties users' perception of clickable buttons. An example of this is the shopping cart button in the upper tab of the main menu that can be seen in Figure 4.15 highlighted in the red circle. Despite its lack of dynamic movement this icon reveals the store menu, where users can by credits and others products related to the game applications.

Usability Tip - Apply dynamic effects and hover effects so buttons can appear clickable to the user.

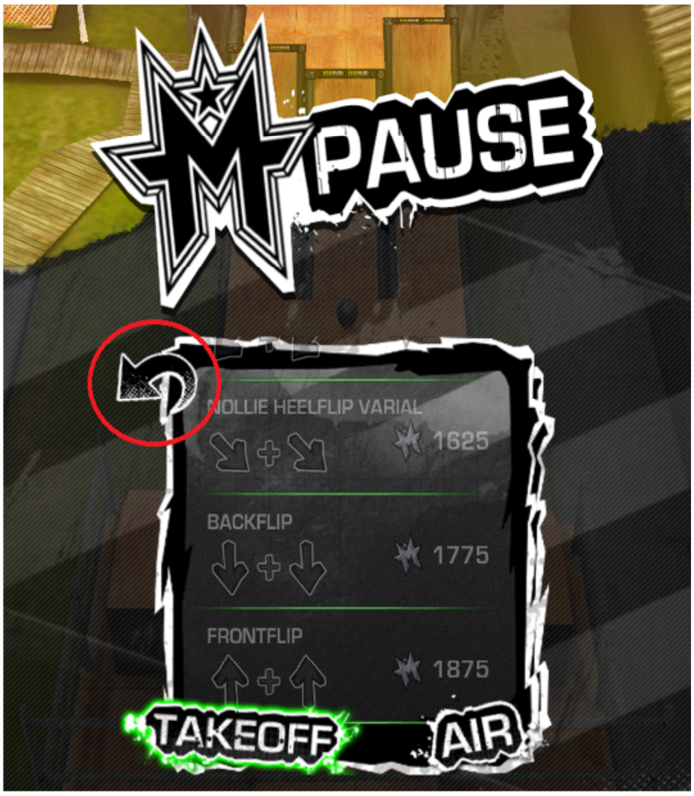

Figure 4.14 - Trickology list in the Pause menu in Megaramp final version

Use appropriate touch actions: Some buttons still do not have an adequate click response time, which leads users to click repetitively to ensure their actions.

Usability Tip - Implement adequate response time in every click or give the user proper feedback of his actions by implementing hover effects that shows the user that buttons have been clicked.

Provide proper feedback: Some of the buttons still do not provide users the proper click/action feedback if either they were clicked or not. Nevertheless this problem was minimized relatively to previous builds, since most of the buttons that had a static movement, now have audio feedback to report whenever there are clicked.

Usability Tip - Implement hover effects, such as, concave shapes or sound effects to give proper feedback and also buttons can appear clickable to users.

Figure 4.15 - Store menu in Megaramp final version

Skip Function: Some of the tutorials displayed in the game applications to not have a skip function to allow users to bounce into the play mode. This might increase users' boredom, especially for expert users, where tutorials display is unnecessary. An example of these non-skipped tutorials can be seen in Figure 4.16.

Usability Tip – Allow users to customize if whether they want tutorials to be displayed or implement a skip button.

Language: This version does not have different language customization. It only supports the English language.

Usability Tip – In order to have a more global access in the applications' market, one should be held into account main language support.

Gameplay: Game shows minor problems in terms of gameplay. The game application sometimes executes tricks without user's command. It also shows some inconsistency in performing some of the tricks.

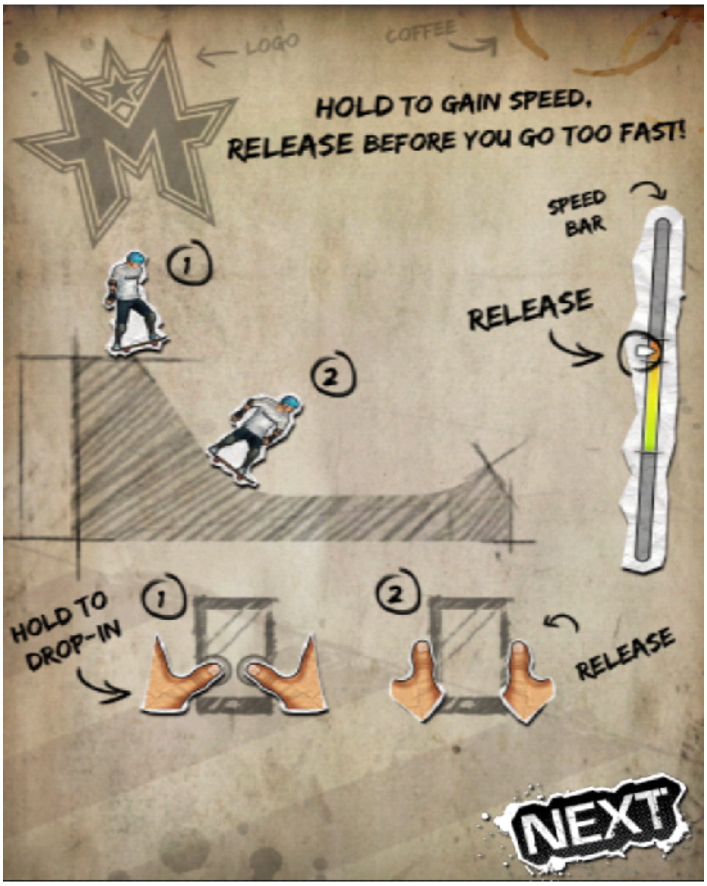

Figure 4.16 - Example of a tutorial view in Megaramp final version

Improvements

Navigation Features: This version displays step by step tutorials to increase users learning experience, as the ones shown in Figure 4.16.

Correct Messages: When users fail to achieve some trick's command or to execute them properly, the application informs user's about their problem. One of these messages can be seen in Figure 4.17 highlighted in a green circle.

Different feedback means: This final build has audio feedback to inform users whenever they click a button and even when entering the play mode. The music changes and starts a new one to inform users they are entering the play mode.

Player's option: The problems with users customize options are now solved and the choices users make in the Customize or Workshop menu are available once they enter the play mode.

Figure 4.17 - Fail example in Megaramp final Version

4.2 Guidelines for Usability Touchscreen Game Applications

Touchscreen Game applications are becoming more and more used due to the up growing market of touchscreen devices. In addition the user classification of these types of applications includes expert, novice and casual users. These characteristics make Game applications a special case in touchscreen applications and the need for guidelines should be induced.

Usability for design and interaction are extremely important in these applications. Since these game applications are fun related, the user has to have a satisfactory interaction otherwise the user is likely to become annoyed and choose another game application. These guidelines were built for game applications, nevertheless they can be helpful for other touchscreen applications. All the literature background and empirical knowledge obtained throughout the partnership with Biodroid and tests made with game applications provided knowledge for the guidelines construction. The guidelines based on the literature review are cited as so, the others derive from the empirical knowledge gathered.

1. **Target size does matter**. Input speed is very important when gamming, icons smaller than fingertips require too much precision. Ensure that the selected target area is larger than the icon itself. This will determine whether or not users commit too many errors or fail to achieve desired outcome. Controls should be large enough to be easily touchable, at least 23x23 pixels (13x13 dialog units or DLUs). Most used icons should be larger (40x40 pixels or 23x32 DLUs) ("Touch," 2012). One can also use 10mm key size for game control buttons on small screens and implement larger key sizes on larger screens (Park & Han, 2010; Sun et al., 2007).

2. **Implement an easy navigation.** Allow clear and direct navigation to return to the main menu or exit. This is especially important if the device does not integrate a physical button dedicated to this. To increase facility for correcting errors, support redo and undo functions (Inostroza et al., 2012; Nielsen, 2005). Do not display too much information at one time; displace them throughout a tutorial with different pages. In addition when showing tables or row information implement a side bar so users can acknowledge where they are in terms of information location and can skip to the end or to the top more easily.

3. **Give importance to icon design and labeling.** A good delineation and a concave surface of the button itself, gives the user a more precise location of the clickable area and therefore increases efficiency. Also implement movement into some key buttons as this will increase their notoriety. Take advantage of user known shapes and implement consistency in icon design throughout the development process (e.g., a home layout for the menu button and a gear shaped icon for the definitions menu) (Inostroza et al., 2012; Nielsen, 2005). If possible supplement a label along with the icon to better understanding or create a hover effect to show a label every time the user selects the icon. Labels should be simple and when used out of the keys must be distinguishable from keys itself. Labels must give users clear information where are they being lead to.

4. **Apply a practical tutorial.** To overpass user annoyance with long tutorials implement the tutorial whilst loadings occur. A background tutorial comes as an important measure because the user can learn how to play whilst playing the game, therefore minimizing the user annoyance and also increased efficiency. Depending on the type of application and the complexity of the instructions sometimes it is preferable to opt for follow-up tutorials, so users can learn properly.

5. **Use the appropriate touch action.** In keyboards the natural response is a press action; once the keyboard is pressed the action occurs. In touch technology sometimes the best strategy is to implement a release response, since this action allows the user to carefully adjust finger position before the action really occurs, therefore minimizing unintended actions. Make sure to have the appropriate response time of click action (1 second or less)

(Shneiderman, 1984). This becomes important especially in high dynamic game applications, such as, first person shooter applications. It is advised to use a strategy that applies naturally to the specific action. Mixing strategies can become confusing, for this reason do not mix more than the necessary (Sjöberg, 2005).

6. **Take full advantage of the touchscreen.** Do not rely only on click-only buttons. Take advantage of touchscreen possible gestures, for example, zooming, panning, scroll, rotate (for details see ("Touch," 2012). An interactive icon that has more than one action, such as, click and scrolling features, can lead the user to make unintended actions. Make gesture actions intuitive and at the same time efficient, so the user can perform intended actions easily.

7. **Design for multiple users.** To make the access easy to different users implement a feature that allows the game application to be mirrored or customized, so that it can be used by right and left-handed people. When possible give the user the opportunity to customize the application (Inostroza et al., 2012). In addition, this feature would avoid arm fatigue and screen obstruction. One should assure some adaptations in order to create a healthy game environment for color-blinds. First one should not rely only on color decisions but also color and icon shapes. Since the most prevalent type is red-green disability, one should avoid red and green colors to be used on decision making icons without shape (Simunovic, 2010). Implement ColorADD® code in icons so users can acknowledge what type of color they upon with (Neiva, 2010).

8. **Locate buttons wisely.** Do not locate clickable buttons within the application main visual area whilst playing and make sure users can perform desired actions, such as, scrolling, without obstructing the content view with their hands. Visual display should allow users to predict where to find desired information; this will increase learnability whilst implementing consistency. If the device is operated in landscape or portrait view, or even both, may use the following tips; **Landscape**: main buttons could be held at the corners and there is the possibility to place icons between them; **Portrait:** main interaction buttons should be held at the corners (preferably in the upper corners) and it is not advised to place buttons in between. Avoid right areas when dealing with one-handed thumb interaction and placed frequently used keys, when not in play mode, in the central area (Park & Han, 2010). Also locate the buttons wisely and consistently so the user can easily access and remember the location.

9. **Provide proper feedback.** Users need to have feedback from their actions. Often used, 3D-effects may provide a button the appearance to have been pressed, but nevertheless this feature in touchscreens sometimes is not conclusive. With finger input the button may be partly obstruct and therefore the 3D-effects is reduced (Sjöberg, 2005). Implement hover

effects, such as colors gradients to change the color when a button is selected.(e.g., when a certain button is selected his color changes so the user can realize his selection). Use the appropriate color conventions for specific actions to promote an easier understanding and increased efficiency (e.g., exit buttons in red and alternatively the undo button in green) (Nielsen, 2005). Furthermore, provide proper feedback of what is entered into the system. If users are entering text, show the characters in a viewable area whilst they are typing to promote a better understanding of what is being typed. Moreover ensure that loadings occurs within the expectable time (not more than 20seconds), and keep the user informed using a loading meter (Reddy, 2008). Finally ensure that correct and simple messages are revealed especially when savings and errors occur (Nielsen, 2005).

10. **Use different feedback ways.** Visual attention is very important for gaming applications therefore the need for different feedback resources to get the user's attention. Tactile feedback is often used and very easy acknowledge by users. (e.g., when user is typing the device vibrates in order to assure the input). Alternatively, sound feedback is very useful to attract user's attention when needed and to provide feedback without obstructing visual attention (Nielsen, 2005). Ensure that audio messages are kept short and simple, also abbreviations are not advised (Tiresias, 2009).

11. **Show only what needs to be shown, where needs to be shown.** Most important or most used features must have a highlighted position. Normally displace them where the user is likely to have his attention; however do not distract the user from its main objective that is to play the game. Often when playing a game the user needs to have exterior feedback from what is happening in is device therefore displace information about new messages and battery status generally placed in the right upper corner of the device screen.

12. **Use menu based features.** Smartly hierarch features to appear in the menus and the most frequently performed features directly on the background instead of in drop-down menus. Also take advantage of side bars and arrow signs for users to properly understand the menus.

13. **Implement a skip function.** In game applications is often required for the user to experience a tutorial in order to better understand how to operate the application. For those tutorials not to cause annoyance between users is advised to implement a skip function so users can skip which ever steps they want. Also the location of these function should be far from the main buttons, so users do not accidently activate them.

14. **Memorize players' options.** Customization of either player avatars or cars, such as, color, type of hair, clothing and others, should be memorized even if the player exits the game. With this feature users do not have to choose their options all over again.

15. **Adapt wireless demand.** In mobile devices wireless network connection foster some problems in terms of its stability and speed. Wireless connection demand should be adapted so the device can support it. Measures such as, when large file download is needed, stable wireless connection should be requested to users, could improve device usability and decrease users' boredom.

16. **Support Graphical adaptation.** Some devices may not support a large amount of dedicated memory for graphical demand and fast processing speed, as a result resolution and graphical definitions should ne configurable when needed. Even though some interfaces do not allow these configurations, such as iOS systems, this feature should be held in mind by applications developers.

17. **Provide Main Languages configuration.** In order to have a more global utilization and be accessed by multiple users, applications should provide main language configuration. Languages such as, English, Spanish, French, Chinese should be available depending on the public market and application insertion (Inostroza et al., 2012; Nielsen, 2005).

18. **Assure the correct Gameplay and reality.** During the game experience assure that the right gameplay is suited for each situation. For example when dealing with a driving experience game assure that the right tire traction and sensitivity are adjusted. Also make sure the game application has the correct realism, such as collision, make sure objects collide properly and implement the correct consequences (e.g. car gets damaged after a collision) (Reddy, 2008).

19. **Use high contrast visual elements.** Text must be clear and readable, also links must be easy to target (Seward, 2011a). Take advantage of yellow and white text placed over dark color backgrounds (Tiresias, 2009).

20. **Implement Help features.** If the game so requires, provide help features so users can acknowledge how to operate the device. Make sure such information can be easily searched, with concrete steps explanation and without being too large (Nielsen, 2005).

These usability proposed guidelines were implemented into the UsaGame as shown in (Annex 1).

4.3 Usability Evaluation Test – Cognitive Walkthrough

The objective of the usability evaluation test is to test usability proposed guidelines that were implemented into UsaGame, and further analysis of the results. Two different versions of the Megaramp game application were tested and compared to analyze the out coming results.

4.3.1 Test Specifications

For the series of tests it was provided reliable wireless connection and an office-like area with adequate environmental conditions, such as, light, temperature and noise that provided a distraction-free environment for the test participants. As mentioned before the usability evaluation test was divided into two tests (Test A and Test B), regarding the two different game stages of the Megaramp game application. Test A tested and initial Megaramp version 1.0#30 and Test B tested a final version #0.9, were some of the usability guidelines were implemented.
First it was hand over one individual copy of the CWP (Annex 2) to each test participant and a brief explanation of its content and test procedures was made. In this first brief period all users' doubts were answered and it was explained that from there on any doubts were not meant to be answered as it may affect test's results. Two iPad devices were made available for testing, one containing the Megaramp version 1.0#30 and the other containing the final version 0.9. In order for the analyzer to evaluate each participant the usability evaluation test was made for one participant at a time. This allowed the analyzer to proper evaluate each participant's test and to note and the metrics and comments necessary.

In order to minimize learnability and so the results could become more accurate as possible in order to evaluate the true usability of both Megaramp versions, half of the 20 users (10) were submitted first to Test A and then to Test B whereas the other half was submitted to Test B first and then to Test A. Both groups were chosen randomly in order not to affect the results. This counterbalancing allowed for more accurate results (Tullis & Albert, 2008).

Throughout the usability evaluation test, users were asked to think aloud so their opinions could be registered and further analyzed. This comes as an important factor to gain insight information about the UX. As it may affect time-on-task usability metrics participants were asked to hold some of their thoughts and to share them after they completed the tasks (Birns et al., 2002 *apud* Tullis & Albert, 2008). After each task all users' difficulties and opinions were noted by the usability analyzer, this way, users did not have to stop their tasks to share their opinions.

4.3.2 Sample size

In the interest of identifying major usability errors, few users can be necessary, generally 4 to 5. But in the pursuit of identifying furthermore usability problems the number of users should increase. The higher the number of test participants the lower the error gets and more accurate results are given (Tullis & Albert, 2008). This study contemplated 20 participants. It is of extreme importance to select representative members for this study as they will reflect the resultant accuracy of the results.

4.3.3 Data Collection

The data collection was performed resourcing to an excel sheet with a task template for quicker notes of users think aloud thoughts as well as usability metrics that derive from the series of tests.

4.3.4 Usability Metrics

In order to verify the usability of the UsaGame and for further analyzes, usability metrics must be registered. According to the following usability attributes: Learnability, Efficiency, Effectiveness and Satisfaction one can determine the metrics used as shown in Table 4.1.

Table 4.1 - Usability Attributes and implied measurements used

Usability Atributes	Measurements
Efficiency	Time-on-task
Effectiveness	Nº of errors + Task success
Satisfaction	User reported data + Behavioral observations

- Time-on-task
  Consists on measuring the amount of time necessary for users to complete a certain task. At the beginning of each task the time countdown starts, and it will finish once the user has completed or has given up to achieve the task (Tullis & Albert, 2008). Recorded time is then inserted into an excel sheet for further analysis.

- Effectiveness
  This usability attribute can be measured by the number of errors users make whilst completing each tasks (Tullis & Albert, 2008). Each action (click) that deviates from the normal procedure to complete each task was assumed as a mistake or error. For task success data collection it was set a binary relation that correlates **0** with failure and **1** with success. This process eases the analysis that was further made in the excel software program.

- User's Satisfaction
  Self-reported data, such as, subjective user satisfaction allows for a direct analysis over the usability experience problems users are faced with. Such data can be retrieved through think aloud process where users are asked to think aloud their thoughts throughout the tests. In addition after each task completion users were asked to share their opinions, whether negative or positive, for the usability analyzer to note them

down. At the end of each test users were asked to give a personal opinion of the overall satisfaction of the game application, among other questions, using Likert scales to choose their appropriate classification (Tullis & Albert, 2008). An example of a type of a Likert scale used in the CWP can be seen next:

Agreement sentence: “I find myself overall satisfied with this game application”

1. Strongly Disagree
2. Disagree
3. Neither agree or disagree
4. Agree
5. Strongly Agree

In addition throughout the usability tests a behavioral analysis was performed in order to acknowledge any signs of users’ unrest. It was asked for users to continue working on each task until completion or until they had reached a point in which in real life they would have given up or seek for assistance (Tullis & Albert, 2008).

4.3.5 Task Selection

In the CWP (Annex 2) each one of the two tests contemplated four equal tasks. These tasks were selected to compare results of the two different game stages in order to analyze the improvements and liability of proposed usability guidelines. Even though each task could be more oriented to test a certain proposed guideline, other usability guidelines analyses were also performed (see sub chapter 5.3.2). All tasks were independent, meaning that if a certain user could not perform such task it would be given the opportunity to proceed for the following task in the same stage as every user would so. The tasks used in the CWP (Annex 2) were the following:

Task 1 – Choose the skate mode, customize your player and your skate and see if they match the ones that appear in play mode.

This task tested the usability guideline nº14 (memorize player’s options) previously showed. Also throughout the task completion participants had the first experience with the game application and therefore navigation problems might arise, such as, different menus navigation perception.

Task 2 – Accomplish the “180 ollie” maneuver in skate mode.

In this task participants were asked to play the game and therefore test the usefulness of the tutorials and the easiness of the gameplay, among others.

Task 3 –Playing in Bmx mode go to pause menu and learn how to perform the "tailwhipp" trick.

In this task users where faced with one of the most crucial features of the Megaramp game application, the possibility to exchange between Skate and Bmx mode. This task will give an opportunity to analyze, among others, the following usability proposed guideline nº2 (Implement an easy navigation) and number 3 (Give importance to icon design and labeling).

Task 4 – Eliminate your saved game and start a new one choosing a character with a different sex than you have before.

This task posed again some menu challenges to participants as they were forced to explore the menus to accomplish the task. It will also test the usability guideline nº 3 (give importance to icon design and labeling).

CHAPTER 5 - RESULTS AND DISCUSSION

In this chapter the results from the usability evaluation test will be presented as well as their discussion. Furthermore it will be discussed the proposed usability guidelines.

5.1 Usability Evaluation Test

Throughout the series of tests the following usability metrics: time-on-task, task success and nº of errors were recorded. Also Likert scales were filled out according to each user's opinion regarding satisfaction and game specific purposes.

Sample

The test was made with 20 users which were randomly chosen for this study. Since the Megaramp game application was an action game with skate and Bmx sports, a higher proportion of man users was intentionally chosen. Therefore the sample contained a higher proportion of male users, i.e. 14 males and 6 females (see Figure 5.1).

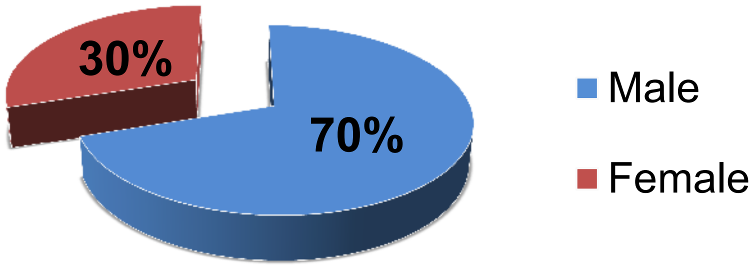

Figure 5.1 - Participants' Sex Percentage in a total of 20 users

The public target of the Megaramp application stands between 15 to 35 year old users. The 20 users were chosen to be representative, as it can be proved by the average age of 24.5 years old (SD=3.10). The academic skills of the users were grouped into High school (5%), Bachelor (35%) and Master degree (60%) users.

Touch Game applications' experience was also asked to users in order to evaluate their experience, using a 5 degree Likert Scale. Being **1** low experience and **5** corresponding to expert users who use touch game application in a daily basis, the average UX with touch game applications was 3 (SD=1). Therefore in this study the three classes of users (novice, casual and expert) were present. By the empirical knowledge obtained throughout the observation of all the users it is possible to suggest the following: Novice users tend to explore within their knowledge and may commit more errors in order to find what they accomplish, which may indicate usability navigation problems; casual and expert users tend to explore the most out of the touch gestures. Expert users may sometimes provide more gameplay specific opinions, such as, click to select instead of swipe to select. Nevertheless all users' opinion provided knowledge about usability problems of the game application.

5.2 Usability Metrics

Here it will be presented the usability metrics results from the usability evaluation test performed to the two different stages of the Megaramp application (Test A and Test B) mentioned before in Table 4.1. First will be shown the usability metrics related to performance metrics and discussed by task comparisons. Secondly will be shown the subjective results obtained through self-reported data from users. Lastly it will be made some test comparisons to the usability metrics. Discussions are made throughout the resulted appearance.

5.2.1 Time-on-task

Time-on-task usability metrics were registered for each task in the two tests as can be seen in Table 5.1. Each cell represents the duration (s) that each user took to try to accomplish each task.

Table 5.1 - Time-on-task metrics

Duration (s) / Users	Test A				Test B			
	Task 1	Task 2	Task 3	Task 4	Task 1	Task 2	Task 3	Task 4
P1	88	270	57	53	81	451	67	72
P2	63	118	74	35	78	18	64	63
P3	33	72	44	19	66	83	59	39
P4	195	93	84	25	148	64	66	45
P5	27	134	102	21	69	132	107	49
P6	68	151	95	125	75	58	90	51
P7	107	189	128	49	99	63	72	57
P8	76	193	55	23	79	97	76	64
P9	37	75	59	19	93	115	45	42
P10	35	193	77	22	79	240	84	56
P11	44	153	81	24	60	74	105	92
P12	55	115	42	30	90	200	60	53
P13	70	376	115	110	107	97	88	53
P14	134	195	86	59	96	113	72	60
P15	117	164	160	49	115	266	56	55
P16	198	439	69	28	95	63	98	42
P17	101	932	238	29	144	141	105	52
P18	90	207	160	29	79	89	75	46
P19	89	160	135	29	94	58	60	41
P20	91	177	89	59	105	131	67	42
Average	85,9	220,3	97,5	41,9	92,6	127,7	75,8	53,7
Median	82,0	170,5	85,0	29,0	91,5	97,0	72,0	52,5
Standard deviation	47,9	190,7	47,9	29,1	23,1	98,5	18,0	12,6
Confidence Interval	21,0	83,6	21,0	12,7	10,1	43,2	7,9	5,5
Lower Bound	64,9	136,7	76,5	29,1	82,5	84,5	67,9	48,2
Upper bound	106,9	303,9	118,5	54,6	102,7	170,8	83,7	59,2

In both Test A and Test B the more time consuming task was task 2, where users were asked to play the game and therefore they were most likely to fail due to inexperience playing the game.

Task 1 was more time-consuming in Test B than in Test A, as can be seen in the average time-on task metrics in Table 5.1. This resulted from the step by step tutorials implemented into the game version of Test B, which led user to take more time to learn the tutorials.
Task 2 was significantly more time-consuming in Test A than in Test B. This can suggest that the implementation of the guideline nº4 in the game version of the Test B increased the game's usability.
Task 3 was more time-consuming in Test A, which can suggest an improvement on the usability of the Trickology list of the game version in Test B that users had to search through, in order to accomplish the task. This improvement can be due to the implementation of the guideline nº3 that improved the icons delineation and the guideline nº19 that improved the text contrast.
Task 4 once again revealed a higher time-on-task result for Test B than Test A. This can be explained through the changes in the Gamedata menu and suggests a low usability of the return button in the Trickology list of the game version of Test B (see Figure 4.14). Both reasons led users to spend more time trying to find a way to the main menu and then again to find the delete button in the Gamedata menu.

In Table 5.1 it is also possible to notice the presence of outliers that is represented by the high time-on-task values. Some examples of outliers were highlighted with red circles. The outliers' existence happens due to the persistency of some users, because it was previously asked for each participant to give up attempting only when in a normal situation they would give up and seek for help.
All statistic results presented in Table 5.1 were made considering a sample size of 20 users and a 95% confidence level resulting in a 5% level of significance. As one can see, standard deviation values indicate a high discrepancy of time per user which indicates different types of user-persistence and learnability.

The average comparisons and their associated confidence intervals with upper and lower bounds can be seen in Figure 5.2.

In Figure 5.2 one can see the average time-on-task values for both tests marked in the orange (Test A) and green (Test B) markers. The black dots illustrate confidence intervals for each average time-on-task. Task 2 demonstrates the higher confidence interval due to the high standard deviation. It is also worth to notice that in Test B the confidence intervals are lower that for Test A, for all tasks. This can demonstrate a better consistency and low discrepancy of time-on-task values for this Test. This can suggest an increase of the game version's usability in Test B.

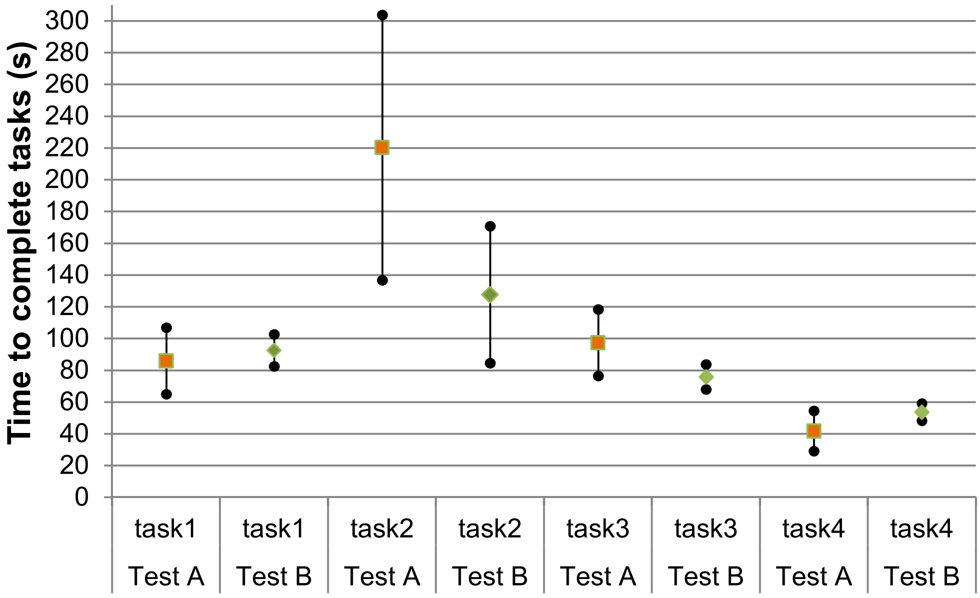

Figure 5.2 - Average time-on-task values and their confidence intervals

5.2.2 Number of Errors

This is the second usability metric that was measured whilst the tests were being performed. In this usability evaluation test with the Megaramp Touch mobile game application, an error was considered as any action that deviates from the accurate path, i.e. unnecessary touch clicks for each task. Being that for the four tasks is given an example of considered errors:

- Task 1 – In this task users had to explore the menu for the first time and every click that deviates themselves from the correct path, was taken into account as an error;
- Task 2 – For this task users had to play the game and therefore errors were considered as a failure in attempting to try the maneuver, which lead them to retry again;
- Task 3 – This task posed some challenges in exploring the Trickology list and its imbedded usefulness. Errors were unnecessary clicks that participants made whilst exploring the Trickology list in order to accomplish the task;
- Task 4 – Again this task posed some even more menu-exploring challenges to the participants in order to achieve this task. Errors were unnecessary clicks that users made in order to delete their saved game.

The average number of errors per task is showed in Figure 5.3.

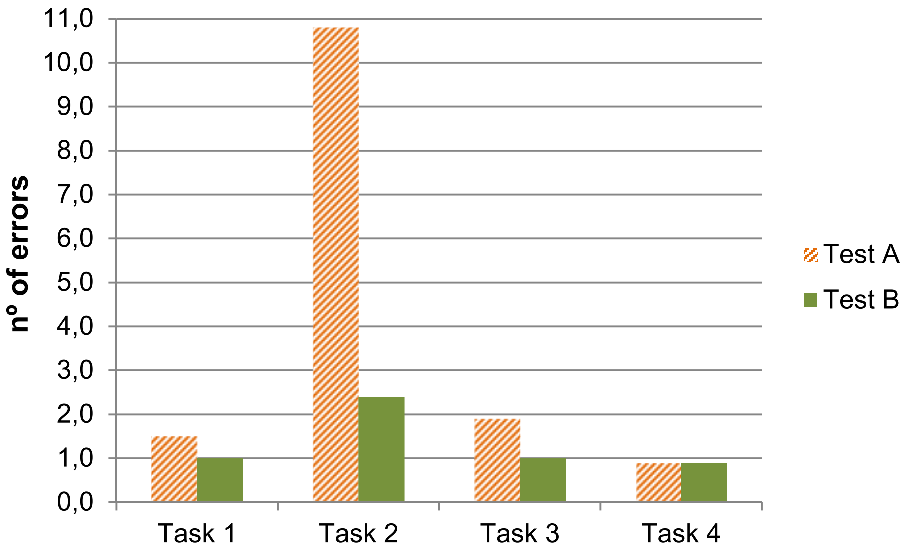

Figure 5.3 - Average number of errors per task

As one can see in Figure 5.3, all tasks from Test A, with the exception of task 4, registered a higher number of errors than Test B. One can highlight Task 2 as being the most difficult task for participants, were they registered the higher number of errors.

Task 1 results can suggest an increase of the buttons' usability in the buttons of the game version in Test B. Therefore one can suggest that the guideline nº10, that suggests the implementation of sound feedback in buttons, contributed for the increased usability in the game version of Test B.

Task 2 results recorded a significant difference between both tests. This was mainly due to lack of explanatory tutorials in the game version of Test A. In the game version of Test B there were implemented some improved tutorials using guideline nº4, which one can suggest that increased the game applications' usability.

Task 3 registered again a higher number of errors per user in Test A, which can suggest an increase in the Trickology list's usability in the game version of Test B (see Figure 4.14), that as a more clear delineation of the icons.

Task 4 registered an equal average number of errors per user. Even though in Test B the game application had a more clear "sex exchange" button, as seen in Figure 5.8, also the Gamedata menu suffered some changes, which can explain the equality in the number of errors of task 4 in both tests.

5.2.3 Task Success

For this usability metric all task success and failures were registered using a binary system correlating **0** with failure or uncompleted tasks and **1** with success or completed tasks.

Table 5.2 shows the total number of completed and uncompleted tasks performed by the 20 users.

Table 5.2 - Total of Task Success

Nº of tasks / Classification	Test A				Test B			
	Task1	Task2	Task3	Task4	Task1	Task2	Task3	Task4
Completed	**19**	**5**	**20**	**20**	**20**	**17**	**20**	**20**
Uncompleted	**1**	**15**	**0**	**0**	**0**	**3**	**0**	**0**

These results show that in Test A there were more uncompleted tasks than Test B, suggesting an increased usability in the game version of Test B. Also task 2 results in the Test A, highlighted in the red circle, registered the highest number of uncompleted tasks whereas the same task 2 in Test B only registered 3 uncompleted tasks. This can be explained by the low usability tutorials in the game version tested in Test A, and suggests an increase in the usability of the tutorials presented in the game version of the Test B, due to the implementation of more explanatory tutorials.

A comparison of the percentage of completed tasks in both tests can be seen in Figure 5.4.

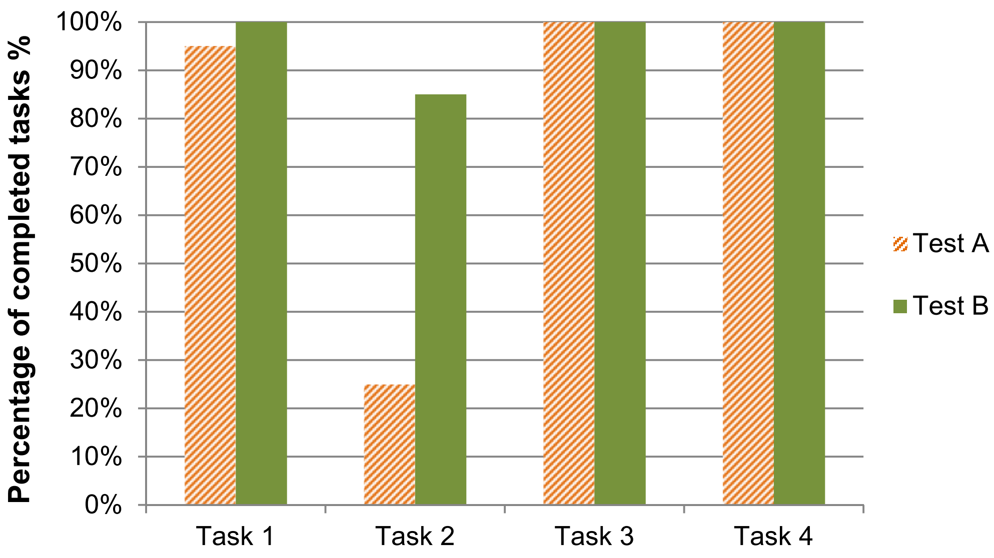

Figure 5.4 - Percentage of completed tasks

It can be well demonstrated in Figure 5.4 the lack of success in Task 2 of Test A. In this task participants were faced with no explanatory tutorials which led them to make a high number of errors and to give up accomplishing the task thus contributing to a high rate of uncompleted tasks. As for Test B it demonstrates a high number of completed tasks, which suggests an increased usability in the game version in which some usability guidelines were implemented.

Figure 5.5 shows the number of users, in a total of 20, with the most completed tasks.

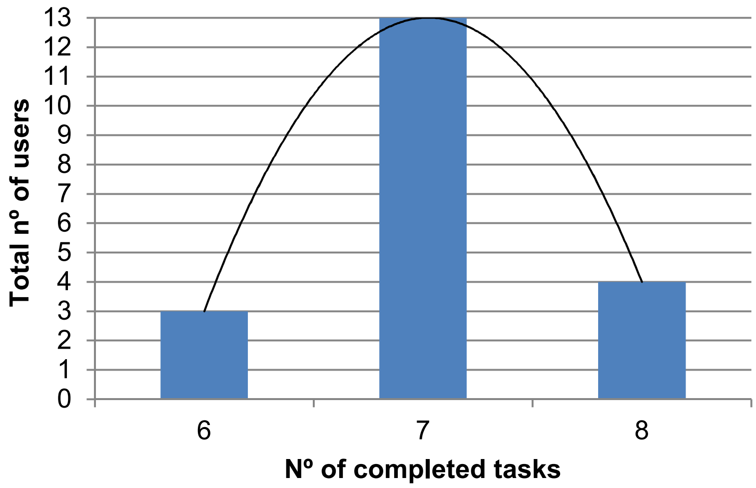

Figure 5.5 - Number of users with most completed tasks

Analyzing Figure 5.5 one can report that the majority of users (13 users) completed seven of the eight total tasks, and few (4 users) completed the entire tasks proposed in the CWP. Also there were no records of users completing less than six tasks. The black line in Figure 5.5 illustrates a tendency line, suggesting a normal distribution on the number of completed tasks that was obtained through the feature “polynomial tendency line” in the Excel® software.

5.2.4 Self-Reported Data

As previously said in the sub-chapter 4.3.4, self-reported data allows a more direct analysis over the UX and contributes to the usability problems’ solution. In this usability evaluation test, users were asked to fill the appropriate Likert scales in the CWP according to each task and furthermore about satisfaction and usefulness of the tutorials. In addition throughout the test’s completion users think aloud comments were fully noted as well as shared comments with the usability evaluator after each task.

In the CWP users were asked to grade the following criteria: Task 2 – easiness, Task 3 - Trickology list usefulness, Gameplay, Design, Tutorials’ usefulness and Overall satisfaction. It was only asked for task 2 easiness because it was the most complicated task for users, as they were faced with the gameplay of the application. It was specifically asked for “Task 3 - Trickology list usefulness” to compare the usefulness of both versions’ lists. The summary of all users’ grade options, using a 5 point Likert Scale, is presented into Table 5.3.

Table 5.3 - Self-Reported grade (5-point Likert scale)

Criteria / Users	Test A - Version 1.0#30						Test B - Final Version					
	Task 2 - easiness	Task 3 - list usefullness	Gameplay rate	Design Rate	Tutorials usefullness	Overall Satisfaction	Task 2 - easyness	Task 3 - List usefullness	Gameplay rate	Design Rate	Tutorials usefullness	Overall Satisfaction
P1	1	1	1	2	2	1	5	4	3	4	3	3
P2	1	3	2	4	1	1	5	2	4	4	4	3
P3	4	3	4	3	4	4	4	4	4	4	4	4
P4	3	2	1	2	1	1	5	4	3	2	3	3
P5	1	1	3	4	2	3	5	3	4	5	4	4
P6	1	3	2	4	2	3	3	4	4	5	4	4
P7	1	3	3	4	1	2	5	2	4	4	4	4
P8	1	4	1	4	2	3	5	4	4	4	3	4
P9	1	2	1	2	1	1	1	2	1	2	3	2
P10	1	2	1	3	1	3	4	3	4	4	4	4
P11	1	2	2	3	1	1	4	3	3	3	4	3
P12	1	3	3	4	2	3	4	4	4	4	4	4
P13	1	3	4	4	2	3	1	3	3	4	4	3
P14	1	3	1	5	1	3	5	5	5	5	3	4
P15	1	1	1	4	2	1	2	4	2	4	3	2
P16	3	2	3	4	3	4	3	4	4	4	4	5
P17	3	1	4	5	3	4	5	3	5	5	4	4
P18	1	3	3	4	2	3	4	4	4	4	5	4
P19	1	2	2	5	1	3	4	5	5	5	5	4
P20	1	2	3	4	2	3	3	4	4	4	4	4
Average	**1,5**	**2,3**	**2,3**	**3,7**	**1,8**	**2,5**	**3,9**	**3,6**	**3,7**	**4**	**3,8**	**3,6**
Mode	**1**	**3**	**1**	**4**	**2**	**3**	**5**	**4**	**4**	**4**	**4**	**4**
Median	**1**	**2**	**2**	**4**	**2**	**3**	**4**	**4**	**4**	**4**	**4**	**4**

As it can be seen in Table 5.3 Test A has the lowest scores in all criteria when compared to Test B. This is suggests that the implementation of some usability proposed guidelines into the game version tested in Test B increased satisfaction and game usability.

The "Task 2 – easiness" refers to the easiness of performing the "180 Ollie" maneuver, therefore the easiness of playing the game. As one can see it corroborates the task 2 unsuccessful rate in Test A, previously showed in Figure 5.4. "Task 2 –easiness" in Test A achieved the lowest score in the 5-point Likert scale, indicating a severe usability problem for users to achieve this task successfully. Comparing "Task 2 easiness" results in both tests, one can suggest an increase in the usability of the tutorials which led to increased easiness for this task.

To assess the internal consistency from the self-reported grades' results in Table 5.3, a reliability analysis was made to each test. This reliability analysis was made using the SPSS® software V19 and resulted in a series of results important to assess the tests' internal consistency, such as, Cronbach Alpha value, criteria-total statistics and criteria correlations. Internal consistency generally provides information about all criteria and the extent to which they all measure the same concept in the test (Tavakol & Dennick, 2011).

Reliability analysis – Test A

Table 5.4 shows the Cronbach Alpha value resultant from the reliability analysis performed to the Test A.

Table 5.4 - Test A Reliability analysis

Test A	
Cronbach's Alpha	N. of Criteria
0.737	6

A Cronbach Alpha value in the interval 0.7< α < 0.95 is considered as an appropriate value, meaning that the correspondent test has an appropriate reliability (Nunnaly J., Bernstein L., 1994 *apud* Tavakol & Dennick, 2011). Being that, Test A Cronbach Alpha value of 0.737 belongs to the previous interval which can suggest an appropriate reliability test. Criteria-total statistics presented in Table 5.5 show the differences in the Cronbach Alpha value if any criteria is deleted, therefore the importance of each criteria.

Table 5.5 - Test A Criteria-Total Statistics

Statistics / Criteria	Test A	
	Corrected Criteria-Total Correlation	Cronbach's Alpha if Criteria Deleted
Task 2 - easiness	0.346	0.734
Task 3 - list usefulness	0.097	0.789
Gameplay rate	0.665	0.635
Design rate	0.348	0.733
Tutorial usefullness	0.640	0.660
Overall satisfaction	0.794	0.587

It is possible to conclude based on Table 5.5 that the criteria "Task 3 – list usefulness" (red circle value), regarding "task 3 - Trickology list usefulness", was one of the criteria that would increase the Cronbach alpha value if deleted. This suggests a decrease of importance in this criterion in the test, as can be seen by the same criteria correlation value of 0.097 that is the lowest one. Overall Satisfaction stands out as the criteria with the highest criteria-total correlation score of 0.794 (green rectangle) which suggests the high importance of this criteria and its vulnerability upon other criteria.

Correlation analysis

In addition to the reliability analysis made it was also performed a factor analysis using the SPSS® software V19. Table 5.6 shows the correlation between all criteria in Test A.

Table 5.6 - Test A Correlation Matrix

Criteria \ Criteria	Test A					
	Task2 - easiness	Task3 - list usefulness	Gameplay rate	Design rate	Tutorial usefullness	Overall satisfaction
Task 2 - easiness	1.000	-0.110	0.386	-0.139	0.655	0.380
Task 3 - list usefullness	-0.110	10.000	0.082	0.185	-0.058	0.221
Gameplay rate	0.386	0.082	1.000	0.382	0.621	0.620
Design rate	-0.139	0.185	0.382	1.000	0.123	0.570
Tutorial usefullness	0.655	-0.058	0.621	0.123	1.000	0.631
Overall Satisfaction	0.380	0.221	0.620	0.570	0.631	1.000

Three highest criteria correlations were observed as marked in the green rectangles in Table 5.6. “Tutorial usefulness” and “Task 2 – Easiness” show the highest correlation of all criteria, which come as expected since the easiness of the task depended on the knowledge of the user to complete such task. Such knowledge results from the usability of the Tutorials and how they explain the game instructions to users. “Overall Satisfaction” achieves the other two highest scores with the correlation with the Gameplay rate and the tutorials’ usefulness. The correlation between satisfaction and gameplay suggest that if users do not find the gameplay so attractive or somehow challenging it is likely for them to have a low satisfaction. Lastly overall satisfaction correlation with the tutorials’ usefulness corroborates the previous correlation between the gameplay and user satisfaction.

Reliability analysis – Test B

Test B was also submitted to a reliability analysis. Tables 5.8, 5.9 and 5.10 were obtained through the SPSS® software V19. The Cronbach Alpha value associated to the Test B can be seen in Table 5.7.

Table 5.7 - Test B Reliability analysis

Test B	
Cronbach's Alpha	N. of Criteria
0.786	6

Test B has a Cronbach Alpha value of 0.786, which belongs to the previous refered interval, thus Test B can be considered an appropriate reliability test, resulting in a less more reliable than Test A. Also analyzing the Cronbach Alpha value of both tests it can be suggested that the number of participants is appropriate for these tests (Tavakol & Dennick, 2011). Other reliability results, such as, criteria-total correlation can be seen in Table 5.8.

Table 5.8 - Test B Criteria-total statistics

Criteria / Statistics	Test B	
Criteria	Corrected Criteria-Total Correlation	Cronbach's Alpha if Criteria Deleted
Task 2 - easiness	0.410	0.813
Task 3 – list usefullness	0.316	0.802
Gameplay rate	0.932	0.641
Design rate	0.641	0.729
Tutorial usefullness	0.352	0.791
Overall satisfaction	0.754	0.712

As a result of improvement in Test B there are three criteria with less importance (red circles in Table 5.8). "Task 2 – easiness", "Task 3 - List usefulness" and "Tutorial usefulness" would contribute for a better Cronbach Alpha value if deleted. Also in Test B all criteria had a very similar score in Table 5.3, which suggests a low dispersion in the test results. These three criteria could become less important for the test results as other criteria could assure the consistency of the test. Therefore Gameplay rate, Design rate and Overall Satisfaction could assume a more important role, which would come as expected since those criteria are the ones with most relevance in terms of a satisfaction analysis.

Correlation analysis

As for the previous test it was also made a correlation analysis to the Test B criteria through the SPSS® software V19. Correlation values between all criteria in Test B can be seen in Table 5.9.

The three highest correlations were marked in the green rectangles in Table 5.9. Overall satisfaction achieves the highest correlation score of all with Gameplay rate. This indicates that the gameplay improvements had an impact on the user satisfaction, which can mainly be due to the implementation of better tutorials in the application tested in Test B (Megaramp final version 0.9).

Table 5.9 - Test B Correlation Matrix

Criteria \ Criteria	Test B					
	Task 2 - easiness	Task 3 - list usefullness	Gameplay rate	Design rate	Tutorial usefullness	Overall satisfaction
Task 2 - easiness	1.000	0.120	0.620	0.281	0.026	0.416
Task 3 - list usefullness	0.120	1.000	0.382	0.346	0.019	0.346
Gameplay rate	$\boxed{0.620}$	0.382	1.000	0.752	0.507	0.827
Design rate	0.281	0.346	$\boxed{0.752}$	1.000	0.398	0.569
Tutorial usefullness	0.026	0.019	0.507	0.398	1.000	0.499
Overall satisfaction	0.416	0.346	$\boxed{0.827}$	0.569	0.499	1.000

Also worth mentioning is the increase on the correlation values in Test B when compared to Test A. This suggests a much more improved game application and more consistent tests' results.

User Comments

During the usability evaluation test all users think aloud comments and post-test comments were registered as well as behavioral observations, such as, unrest or impatience from users when failing tasks.

Table 5.10 enunciates the usability problems reported from users and their frequency in a total of 20 users.

It can be seen in Table 5.10 that the problem with most complaints was related with the tutorials in Test A. This can due to the lack of usability in the tutorials of the game version tested in Test A. The tutorials problems related with Test B were referent to the background tutorials that users find a bit confused.

The following most complaint problem was related with the slow button response and button clickable appearance. There were some remarkable complaints related to the Trickology list usefulness in the pause menu, such as, the lack of a side bar in the list for a better navigation experience. This corroborates the importance of the proposed guideline nº2 (chapter 4) that suggests the implementation of such feature to increase the usability. Some users also complaint with the lack of contrast in the Trickology list which meets the usability proposed guidelines nº 9.

Table 5.10 - Usability Problems reported by 20 users and their frequency

Nº	Usability Problems	Test A	Test B
1	Tutorial problems	17	11
2	Lack of button feedback	4	4
3	Slow button reponse	10	7
4	Lists should appear in alphabetic order	5	6
5	Lack of contrast in the Trickology list	6	2
6	List's swipe navigation problems	4	2
7	Sex exchange button placement problems	4	1
8	Sex exchange button should be bigger	2	1
9	Click for selection instead of swiping	1	1
10	User tries to use giroscope	3	0
11	Trickology list should be bigger	4	3
12	Unrest with non-explaining tutorials	2	0
13	Buttons should appear clickable	4	8
14	BMX/Skate button should appear clickable	2	0
15	Speed side bar is not explained	4	0
16	Problem understanding if it is to play with both or only one thumb	2	1
17	In Workshop menu, skate and Bmx should be steady	1	0
18	Tutorials should not appear always	0	4
19	Game should not reboot after profile deletion	0	2
20	No Side bar implementation in the lists	3	3
Total		78	56

The following most complaint problem was related with the slow button response and button clickable appearance. There were some remarkable complaints related to the Trickology list usefulness in the pause menu, such as, the lack of a side bar in the list for a better navigation experience. This corroborates the importance of the proposed guideline nº2 (Chapter 4) that suggests the implementation of such feature to increase the usability. Some users also complaint with the lack of contrast in the Trickology list which meets the usability proposed guideline nº 9.

Table 5.11 gathers all users' positive aspects resultant from their experience with both versions of the Megaramp game application.

Positive aspects are related with game improvements implemented with UsaGame guidelines. An example of well-established usability proposed guidelines is the implementation of user-known button shapes, such as, x and mark signs (see Figure 4.8), as proposed in usability guideline nº3.

Table 5.11 - Positive Aspects reported from users and their frequency

Positive Aspects	Test A	Test B
Buttons' consistency helps decision making	1	0
Game explains the cause of the problem	0	1
Tutorials have improved	0	17
User known shapes (x and mark) help decision making	12	5

The implementation of better tutorials, explaining the game instruction before the user is actually playing, allowed for positive comments from users. Even though not many users commented it is also worth mention the importance of button location consistency throughout the whole game application, as proposed in usability guideline nº8.

In addition to the previously showed comments users also shared some suggestions which are shown in Table 5.12.

Table 5.12 - User Suggestions

1	Glove outfit option
2	Skill type should be in play menu
3	Gamedata menu should have a more suited background image
4	Multiple profile option
5	In workshop skate should be steady
6	Trick search option
7	Click selection instead of swiping (character)
8	Return option when customizing
9	Arrows indicating directions for better navigation
10	Include trick ilustrative Example

Even though some of these suggestions are specific for the Megaramp Game application nevertheless they can be implemented in other game applications. Consider for example, the user suggestion to include arrow signs in order to fully instruct users where they can explore. This feature increases the navigability whilst implementing usability in the game, as the game navigation will become more intuitive for users. Other example that can be implemented into many other game applications is the multiple profile creation, which allows different users to use the same application. This can become interesting for tablet applications, since they are commonly shared devices whereas smartphones tend to become more personal.

5.2.5 Test comparisons

It was made some improvement's analysis to compare improvements in both tests. For those analysis some usability metrics where compared, such as, time-on-task, task success and the average number of errors per user.

Time-on-task improvements

Comparing time-on-task results from both tests one can assess the percentage of improvement in the time-on task metric from Test A to Test B as seen in Figure 5.6.

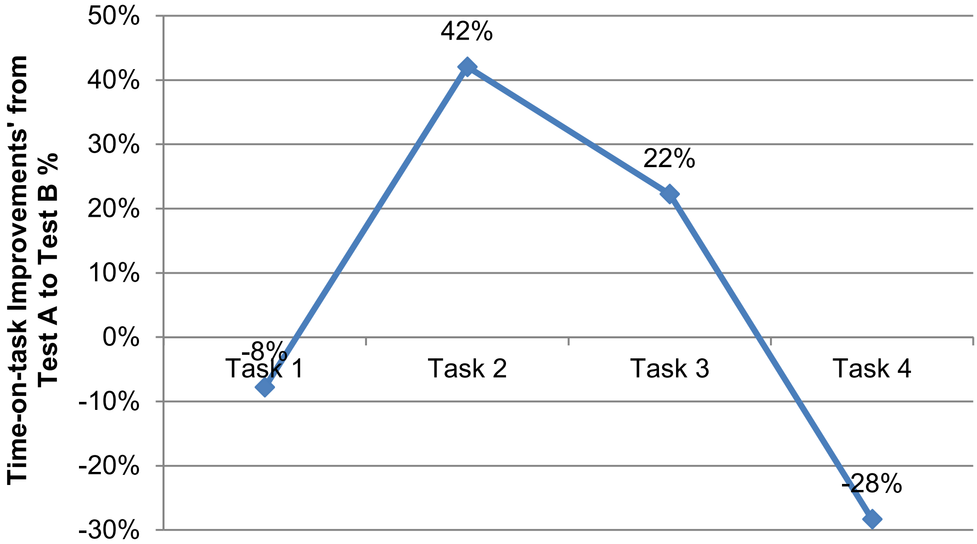

Figure 5.6 - Time reduction percentage from Test A to Test B

Task 1 and Task 4 registered a negative improvement, which does not mean that the usability of the game application has decreased; as a matter of fact this can be due to minor changes in the game that led tasks to become more time-consuming. An example of this is the implementation of better tutorials into the Megaramp application tested in Test B which led users to consume more time in order to read and understand the tutorials.

Task 2 registered the highest improvement percentage that can be due to the implementation of the explanatory tutorials into the application in Test B.

Task 3 registered also a positive improvement in the time-on-task metric, which suggests an increase in the usability of the Trickology list in the Test B.

These improvements provide a positive feedback of some of the proposed guidelines that were implemented into the final game version of the Megaramp that was tested in Test B. Megaramp final version 0.9 improvements proved to be effective for some tasks and allow for less time consuming tasks.

Improvements in the number of errors

It was also performed a comparison analysis over the average number of errors occurred. Figure 5.7 shows the number of errors reduction percentage per user, from Test A to Test B.

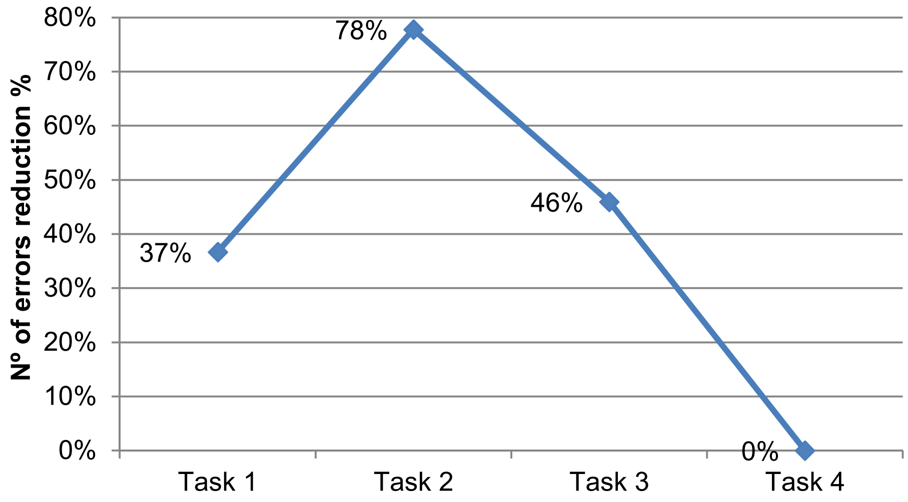

Figure 5.7 - Number of errors reduction percentage

Task 1 registered a 37% decrease in the average number of errors per user, which suggests some improvements in Test B. These improvements suggest that the implementation of button sound feedback in some buttons, resulted in less unnecessary clicks from users to understand if their actions.

Task 2 scored the highest reduction percentage of all tasks, with 78% decrease in the average number of errors per user. This can be mainly due to the implementation of new and improved tutorials which can suggest an increase of the usability of these new tutorials implemented into the final version of the Megaramp tested in Test B.

Task 3 also registered a positive reduction in the number of errors, with a 46% decrease, which suggests that new icon delineation increased the usability of the Trickology list.

Finally task 4 registered 0% improvement, meaning that the average number of errors per users in both tests was the same as seen in the previous Figure 5.3. This does not mean that the usability of the game has not improved in this task. As a matter of fact in this task users were faced with a different Gamedata menu which may led them to a more-time consuming task. On the other hand the icon delineation of the “sex exchange” button in Test B version has improved as seen in Figure 5.8 which can result in a better usability of this button.

Comparing both player option menus from both tests one can acknowledge some improvements. The “sex exchange” button in the lowest righter corner of each menu in Figure 5.8 has increased its size and delineation and also the simplified menu in Test B version can enhanced the “sex exchange” button notoriety.

(a) (b)

Figure 5.8 - Comparison of the Player options' menu in Test A (a) and Test B (b)

Task success improvements

Performing a task success comparison of both tests once can acknowledge that the success rate improved in some tasks from Test A to Test B. Figure 5.9 illustrates the task success improvement's percentage per task.

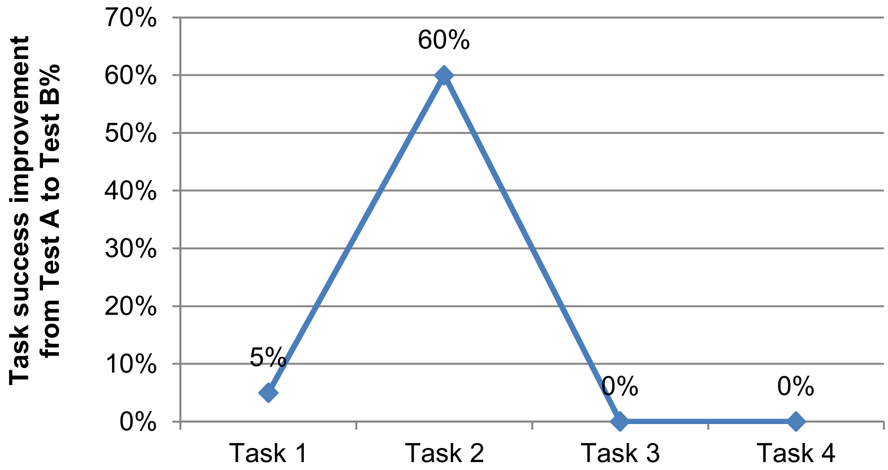

Figure 5.9 - Task Success improvements' from Test A to Test B

Task 1 registered 5% of improvement on the success rate resulting from all users' task achievement and conclusion. Task 2 registered the highest improvement on the success rate with 60% of improvement, that can be mainly due to the implementation of new and better tutorials in the game version of Test B. Task 3 and Task 4 maintained the same 100% of completed tasks therefore no improvements where registered in this field.

Radar graph comparisons

In addition to the previous usability metric analysis it was also made a comparison for the both tests using the following topics: Tasks success, Average Overall Satisfaction, Tutorial Usefulness, Gameplay rate and Task 2 easiness as shown in Figure 5.10.

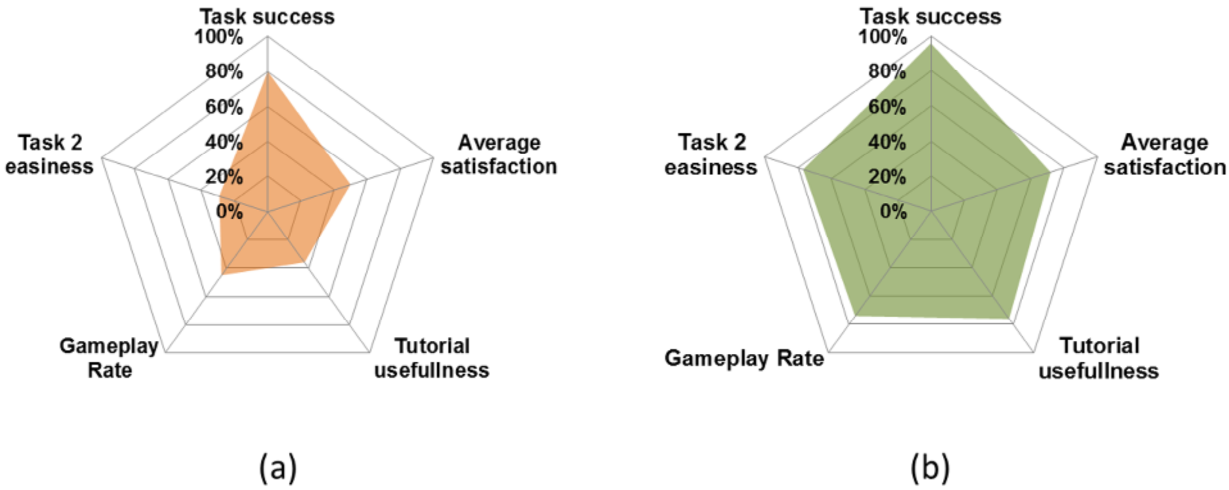

Figure 5.10 - Comparisons between Test A (a) and Test B (b)

From the analysis to Figure 5.10 there are remarkable improvements from Test A to Test B. It is clearly evidential that Test B registered major improvements not only in some fields but in the five criteria mentioned earlier. One can suggest that the implementation of the UsaGame into the development process of the Megaramp application contributed for an increased usability in the Megaramp Game application.

5.3 Final Discussions

Results from the usability evaluation test provided an analysis to the usability proposed guidelines, whether implemented or not in the Megaramp Game application. Here it will be presented some general analysis to both tests as well as the discussion of each proposed guideline.

5.3.1 Test – Analysis

Regarding time-on-task usability metrics task 2 of Test A registered some higher outliers and also registered a superior time-on-task average value when compared to task 2 of Test B. This

can be due to several factors including: different user-persistency and lack of some crucial usability guidelines in Test A version, such as, explanatory tutorial implementation. These factors contributed to a high discrepancy of time-on-task values which was confirmed through the high standard deviation values for task 2 in both tests. High standard deviation values in Test A resulted in an increased confidence interval when compared with Test B (see Table 5.1). The lack of usability in the background tutorials available in Megaramp version 1.0#30 (tested in Test A) contributed to a high number of errors in task 2. This proved to be the most crucial usability problem in order for users to acknowledge how to play the game application, and therefore task 2 was the most time consuming task.
Test A registered the lowest task success rate and registered the high number of uncompleted tasks in task 2 with 15 uncompleted tasks against 5 completed tasks (see Table 5.2). In what regards user grades Test A registered the lowest scores when comparing both tests. Within Test A, the criterion “Task 2 – easiness” was the one with the lowest score which corroborates previous information about this task. Lastly Test A received the higher number of complaints from users, being those mostly caused by usability problems, such as, tutorial lack of usability and button lack of feedback.

The implementation of follow-up tutorials in Megaramp final version 0.9 (Test A) allowed for improved results, such as, less time consuming tasks, increased task success and increased satisfaction. Even though those follow-up tutorials in Test B version fully instructed users, there were still some usability problems with the background tutorials (e.g., Figure 4.16), therefore tutorial complaints remained in Test B.

5.3.2 Guidelines’ importance

The implementation of the UsaGame contributed to the tests’ improvements and the final Megaramp version increased usability. Performing an analysis to all proposed guidelines implemented into the UsaGame, it is possible to notice their importance, whether or not their where applied into the game application.

Guideline 1 – Overall the game application was well designed in terms of buttons size, excluding some minor buttons, such as, sex button size and the Trickology list size that did not took full advantage of the iPad screen size.

Guideline 2 – This guideline was partially applied, since it suggests different features. Undo features were majorly applied which increased usability but in some situations even users referred that undo buttons should be applied (e.g., when customizing clothes). Even though the final version of Megaramp (Test B) included follow-up tutorials that users could skip from page to page of the tutorial learning all different steps, it did not have an undo feature that allowed users to turn to the previous tutorials. Nevertheless one of the major failures in usability regarding this guideline was the lack of a side bar in lists to promote a better navigation. This feature becomes essential for users to acknowledge their exploring possibilities and their whereabouts, especially when dealing with list information.

Guideline 3 – Lack of users' clickable buttons' knowledge outstood the importance of a well-designed button. Some buttons in the game had no dynamic movement which difficult user's perception. Nevertheless their design could be improved with a concave surface to increase their efficiency. One of the main buttons in the game the BMX/Skate button (see Figure 4.6) was even unnoticed by 2 of the users due to its lack of clickable appearance. The majority of users shared the importance of user known shapes in buttons, such as illustrated in Figure 4.8. This increased their decision making as it became evident which button to click.

Guideline 4 – Background tutorials were applied as suggested but nevertheless their usability was poor. As seen in Table 5.10 some users reported the lack of usability of the background tutorials due to non-labeling the steps and misunderstood of those steps. They also commented the need for arrow signs in order to rapidly understand each step's touch movement. This lack of usability led to some unrest and impatience among users whilst performing their tasks. Misunderstanding of the background tutorials even led 3 users to try to use the gyroscope to perform their actions, which is not an active function in this game application. Even though the background tutorials clearly suggested the use of both thumbs in the play mode (see Figure 4.12) further ahead users had to perform maneuvers using only one finger which accorded to some users difficult the handling of the iPad device.

Guideline 5 – Released response actions were adopted which allowed for users to re-think their actions when pressing the touch surface. Some users commented on the fact that it was more natural for them to click for the characters' selection instead of swipe sideways and have to click to select. The appropriate response time is highly recommended or must be interlinked with buttons click feedback, such as, sound or hover-effects feedback. The majority of users shared the fact that the buttons' response was to slow and even more they lacked on feedback. Therefore it is advisable to implement adequate response time and apply button click feedback.

Guideline 6 – The touch technology possible gestures were taken into account and all promoted different types of actions, such as, slide and swipe. As mentioned by some users (see Table 5.12) some actions should be more explained or arrow signs should be applied to promote better understanding.

Guideline 7 – The game application can be played by either left or right-handed users which eliminated the need for a customization in this field. As mentioned before the implementation of user known shapes in buttons instead of just colored ones increased their understanding for color-blind users.

Guideline 8 – This guideline suggested the implementation of button consistency location to promote users' intuitiveness. The button consistency applied in the game was also highlighted (see Table 5.11) as a positive aspect for one user. It is of extreme importance this button location to increase intuitiveness, learnability and therefore increase usability. As for button location some users commented the misplacement of the sex change button, placed in the lower right corner of the iPad screen as seen in Figure 4.10. As suggested to be placed in the lower corners their placement should be also judge wisely. In this case the sex button lack of dynamic movement and clickable design placed a negative effect on the buttons appearance.

Guideline 9 – As mentioned before the proper feedback is extremely important to increase the usability. As referenced before in Table 5.10 some users commented on the lack of feedback from buttons. This allied with the slow response led users to click buttons repetitively and show some sign of unrest and impatience. Proper color conventions where applied even though they were interlinked with user known shapes. Loadings occurred within the appropriate time (less than 20 seconds) as suggested. Also one of the positive aspects pointed out by one user was the correct error messages that the game provided once the users failed its attempt, as it can be seen in Figure 4.17.

Guideline 10 – Even though tactile feedback was not available in both game stages, sound feedback was implemented in some buttons of the final version 0.9 tested in Test B, which allowed for users to acknowledge their clicks and when they were entering the game.

Guideline 11 – This guideline meets button wise placement discussed before and the importance to simplify what is shown to users in order not to overload the user with information. This was generally used in the game, but better adapted in the final version tested in Test B. One example of this simplification can be seen in Figure 5.8.

Guideline 12 – Menu based features were implemented even though they lacked on arrow sign or side bars indicating their location, as suggested in the guideline.

Guideline 13 – A skip function was not applied to tutorials as they keep showing up. Some users (4 in total) stressed the need for tutorials to not appear every single time the user had to retry. This emphasizes the importance of a skip function or a customize function to choose whether or not tutorials appear every time.

Guideline 14 – Memorize players' options is important to increase user satisfaction. Most users' complaint about the non-existence of this feature in the game application tested in Test A.

Guideline 15 – It was not necessary to adapt the wireless demand in this application because the visualization of the videos on the Theater menu depended on the device's internet browser and reliability of the wireless connection therefore it was external to the game application itself.

Guideline 16 – Graphical adaptation was not possible in the iPad device tested, therefore this guideline was skipped. Nevertheless its importance becomes relevant in less than optimal devices.

Guideline 17 – Main language configuration option was available in the Megaramp 1.0#30 version tested in Test A, nevertheless it was not functional. In the final version (Test B) this option was deleted and the application was only available in English. This posed some challenges in less-familiarized English users. Therefore the need of main language configuration is an advisable feature.

Guideline 18 – The gameplay of the Megaramp application was improved throughout the different development builds (Versions), as different measures were applied (e.g., improved collision reality). Therefore the correct realism and gameplay are of extreme importance to increase applications' usability.

Guideline 19 – Some users' complaint about the lack of contrast in the Trickology list shown in the pause menu in the Test A version, but in the Test B version the contrast was improved which enhanced the Trickology list usefulness (see Figure 4.14). Therefore the clear display of information should be applied as suggested. High contrast text was applied in the game application. For example the main menu feature buttons displayed in Figure 4.6.

Guideline 20 – With the improved tutorials in the game version tested in Test B the help feature became less important. Nevertheless one user suggested the use of a search feature to find the desired tricks. Therefore the help or search feature should be held in mind.

In terms of conclusion one can suggest that the proposed guidelines helped increasing the game's usability.

CHAPTER 6 - CONCLUSIONS AND FURTHER RESEARCH

6.1 Conclusions

Developing new usability guidelines well adapted for game mobile touch applications was one of the main challenges of this study. The literature review background and the empirical knowledge gathered through the game tests made and, a partnership with a game development company (Biodroid) allowed for the adaptation of previous guidelines and also the creation of new ones for touch game applications.

The goal of this study was to bridge a gap in game applications' usability research. For this purpose the UsaGame checklist was created to support the development of usability touch game applications. The UsaGame aims to support application developers to instill user-centered design into their applications.

The results observed in the usability evaluation tests were promising. There were made two tests, Test A tested and initial game version whereas Test B tested a final version of the Megaramp. In fact, it became evident that the game version tested in Test B (which was developed using UsaGame) presented significant improvements compared with the other version. Time-on-task metrics registered some considerable improvements from Test A to Test B. Some more improvements were registered in the number of errors of Test B, which were significantly lower than for Test A, suggesting an increase in the usability of the game application developed with the UsaGame. The most important results are related with the self-reported data from users that registered higher levels of satisfaction in the game application tests in Test B. This test also recorded very similar results in the self-reported data from users which can suggest a more developed game in terms of usability.
Results also suggested the high importance of usability tutorials for game applications especially for applications that require too much gesture maneuvers and actions. It can also be suggested the high importance of a good level of usability gameplay for touch mobile devices.

Touch commands can sometimes become challenging to execute therefore the importance of usability concerns can make the difference between failure and success in terms of applications' acceptance. Also, results of the analyses demonstrated the importance of the usability guidelines implemented into the game application and that can be easily comprehended through the tests' improvements. Furthermore results allowed for an analysis to all the proposed guidelines, even such ones that were not implemented into to the game application. This contributed greatly for the evaluation of the guidelines.
By previous establishing a methodology for the UsaGame Development it allowed to have a wide view of the whole process and better scheduling of the activities.

As in previous study (Ji et al., 2006) a greater number of usability problems were found through the UsaGame whilst performing the initial tests in chapter 4 than in the usability evaluation test with the CWP. Suggesting the importance of such type of checklists, checklists can be more elaborate, co-discovering the same problems as usability testing but also disclose other usability problems (Ji et al., 2006).

Some final remarks can suggest that this study supports the statement that the UsaGame checklist contributed to improve usability of touchscreen game applications, therefore it is reasonable to affirm that UsaGame is a valuable tool to support user-centered design in the fast growing field of game development.

Hopefully the outputs from this study such as: the proposed guidelines, the UsaGame checklist, and the results, can help future researchers as well as game application developers. A paper containing part of this study was already accepted in the 15th International Conference on Human-Computer Interaction.

6.2 Further Research

In the field of Touch Game mobile applications future research can be made to improve the proposed guidelines and furthermore develop new ones. Also improvements can be made testing the proposed guidelines with other game applications.

Future research can be made adapting the UsaGame guidelines to other types of mobile applications.

Even though the proposed guidelines where made bearing in mind the iPad device and are for touch game applications further research can be made to create usability guidelines better adapted to each type of touch technology (e.g., resistive, capacitive), each type of device (e.g., smartphones, kiosks) and ways of interaction (e.g., hands, stylus, gloved hands).

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ANNEXES

Annex 1 – UsaGame Checklist

One must use Annex 1 during the development of the mobile touch application and must tick the appropriate status circle according to each one of the requirements. The red circle (No) represents the absent of the requirement in the application. The yellow circle (+/-) indicates that the requirement is not fully applied yet. The green circle (Yes) indicates that the requirement is fully applied into the application. And finally the blank circle (N/A) indicates that such requirement is non-applicable to the application. For each requirement there is also a space for some observations of the requirements, such as, problems to solve.

	Requirements	Brief explanation	Status				Observations
			No	+/-	Yes	N/A	
1	Target area	Ensure that the selected area is larger than the icon itself					
2	Controls size	Controls should be touchable, at least 23x23 pixels or 6mmx6mm. Most used icons should be 40x40 pixels or 10,6x10,6 mm.					
3	Easy navigation	Allow clear and direct navigation to return to the main menu or exit					
4	Navigation Features	Support Redo and Undo					
5	Navigation Features	Do not display too much information , use skipped tutorial and various pages					
6	Navigation Features	Implement a side bar when row or column information is used, for a better knowledge of information location and to skip to end and top in a faster way.					
7	Icon Design	Good delination of the icon gives the users a more precise location of the button , use concave surfaces or movement					
8	Icon shapes	Take advantage of user known shapes and implement consistency throughout the process					
9	Icon label	Use simple labels along with the icon or create a hover effect to show the label once the button is selected					
10	High contrast visual elements	text must be readable and links easy to target, use white or yellow text over dark color backgrounds					
11	Pratical Tutorial	Implement tutorial while loadings occur or implement a background tutorial whilst the user is playing the game					
12	Use appropriate touch actions	Implement release response actions					
13	Use appropriate touch actions	Implement the appropriate response time upon clicking					
14	Use appropriate touch actions	minimize touch inputs, such as, click to select and click to ok					

	Requirements	Brief explanation	Status				Observations
			No	+/-	Yes	N/A	
15	Support touch gestures	Take advantage of touch gestures, such as, zooming, panning, scroll, rotate and make them intuitive to users					
16	Design for multiple users	Implement a feature that allows the application to be used by left and right-handed, or allow the opportunity to configure icons and impliced actions					
17	Design for multiple users	Avoid the use of red and green in critical decision tasks without symbols					
18	Design for multiple users	Implement a customize feature for coulour-blinds, that implements symbols (ColorADD®) into icons so users can acknowledge colours					
19	Button Location	Avoid right screen areas hen dealing with one-handed thumb interaction					
20	Button location in Landscape mode	Main buttons should be held near the lower corners within thumbs reach and there is the possibility to place icons in between					
21	Button location in Portrait mode	Main buttons should be held near the lower corners within thumbs reach and is not adviced to place buttons in between					
22	Button consistency	Locate buttons wisely and with consistency to increase learnability					
23	Provide propper feedback	Use 3D-effects in buttons to appear clicked, also implement hover effects, such as color gradients to change button color when selected.					
24	Intuitive colors	Use appropriate color conventions for specific actions (e.g., exit buttons in red and undo buttons in green)					
25	Characters need to be viewed	Show characters in a viewable area whilst users are typing to promote a better understanding					
26	Appropriate loadings	Ensure an expectable loading time(not more than 20 seconds), and implement a loading meter					
27	Correct messages	Ensure simple and correct messages are shown whenever erros or savings occur					
28	Use different feedback means	Implement tactile and sound feedback so users can have kwowledge of what happens without obstructing visual attention.					
29	Audio Messages	Ensure that audio messages are kept short and simple, abreviation use is not advised					
30	Exterior feedback	Provide exterior feedback for new messages and device battery status. Generally placed in the right upper corner.					

	Requirements	Brief explanation	Status				Observations
			No	+/-	Yes	N/A	
31	Menu based features	Smartly hierarch features to appear in menus. Most important features must have a highlighted position and be placed directly on the background instead of in drop-down menus.					
32	Skip function	Skip buttons should be available in some tutorials and its location should be far from the main buttons, so users do not accidentaly activate them.					
33	Memorize players options	Customization of heither players or cars, should be memorized even if the player quits the game, this way the user does not have to choose it all over again.					
34	Wireless connection	Wireless network connection should not be demanding enought that the device cannot support the wireless network connection needed by the game application.					
35	Graphical support adaptation	Some devices may not support a large amount of memory dedicated for graphics and fast processing speed, therefore resolution and graphical definitions should be configurable when needed.					
36	Language	For the application to be used by multiple users main languages, such as, English, Spanish, French, Chinese, must be available, depending on the public market.					
37	Correct Gameplay	Assure the correct gameplay, depending on the game application being evaluated					
38	Portrayal of real life	Make sure objects colide properly and with the appropriate consequences					
39	Help and documentation	Implement help features					

Annex 2 – Cognitive Walkthrough Protocol (CWP)

1.Instructions

The objective of this usability evaluation test is for Participants to assess the usability of the touchscreen mobile game application (Megaramp) using the iPad device.

Usability Evaluation test's duration will be about 25 minutes.

It will be divided into two tests:

- First test will test Megaramp 1.0#30 version
- Second test will test Megaramp final version

Protocol must be filled accordingly:

a. Part One must be filled before the two tests start
b. Half of the users must start with Test A
c. The other half must start with Test B
d. After finishing the designated test users must perform the remaining Test

After each task participants are asked to grade some criteria, using the appropriate Likert scale. In each test participants must perform the following tasks:

Task 1 - Choose the Skate mode and customize your player and your skate and see if they match the ones that appear in play mode.

Task 2 - Accomplish the "180 ollie" maneuver in skate mode.

Task 3 - Playing in Bmx mode go to pause menu and learn how to perform the "tailwhip" trick.

Task 4 - Eliminate your saved game and start a new one choosing a character with a different sex than you have before.

During the test, participants are asked to "think aloud" what they experience whilst accomplishing tasks in order to the usability analyzer to note them down.

Participants should continue to work on each task until they complete it or reach a point where they would normally give up and seek for help. The objective of this test is to test the game itself and not the participants in question.

Participants should make themselves familiar with this protocol to clear any doubts as further on no questions will be solved as they may interfere with the test's results.

1.1 - Personal Data

Your personal data will serve only for the purposes of this study and will not be shared.

Name: _______________________________________

Age: ______

Sex: ______

Academic Skills (if not finished, mark the current):

High school	Bachelor	Masters

Do you have experience with Touchscreen Game applications (tick appropriate grade):

None	Low experience	Medium experience	Good Experience	Use them frequently
1	2	3	4	5

TEST A - Megaramp Version 1.0#30

Upon starting, create a new game, choose the character of your preference and carry out task completion.

<u>Task one:</u>

Choose the Skate mode, customize your player and your skate and see if they match the ones that appear in play mode (remind to think out loud).

Steps:

1. Customize the Player and the Skate;
2. Enter the play mode and learn the tutorials;
3. Confirm player customizations (Do not play).

Usability analyzer will ask you for some comments. You can only continue after those have been asked.

<u>Task two:</u>

Accomplish the “180 ollie” maneuver in skate mode (remind to think out loud).

Steps:

1. Perform the first level
2. In the second level perform “180 Ollie” maneuver

How easy or difficult it was to perform such maneuver (tick the appropriate grade):

Not completed	Hard to execute	Neither hard nor easy	Easy to execute	Very easy to execute
1	2	3	4	5

Usability analyzer will ask you for some comments. You can only continue after those have been asked.

Task three:

Playing in Bmx mode go to pause menu and learn how to perform the "tailwhip" trick (remind to think out loud).

Steps:

1. Return to the main menu and choose BMX mode;
2. Start the play mode and enter pause menu;
3. In the pause menu find how to perform "tailwhip" trick.

If found, rate the usefulness of the Trickology list found (tick the appropriate grade):

Not useful				Very useful
1	2	3	4	5

Usability analyzer will ask you for some comments. You can only continue after those have been asked.

Task four:

Eliminate your saved game and start a new one choosing a character with a different sex than you have before (remind to think out aloud).

Usability analyzer will ask you for some comments. You can only continue after those have been asked.

Satisfaction

How do you rate the gameplay of the application:

Poor	Adequate	Satisfactory	Good	Very Good
1	2	3	4	5

How do you rate the design of the game application:

Poor	Adequate	Satisfactory	Good	Very Good
1	2	3	4	5

How do you rate the usefulness of the tutorials showed:

Poor	Adequate	Satisfactory	Good	Very Good
1	2	3	4	5

Usability analyzer will ask you for some comments. You can only continue after those have been asked.

Would you use this game application again? Would you recommend it to someone? Why?

If you could what would you improve in this game application?

I Find myself overall satisfied with this game application (tick your appropriate grade) :

Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
1	2	3	4	5

TEST B - Megaramp Final Version

Upon starting, create a new game, choose the character of your preference and carry out task completion.

<u>Task one:</u>

Choose the Skate mode, customize your player and your skate and see if they match the ones that appear in play mode (remind to think out loud).

Steps:

1. Customize the Player and the Skate;
2. Enter the play mode and learn the tutorials;
3. Confirm player customizations (Do not play).

Usability analyzer will ask you for some comments. You can only continue after those have been asked.

<u>Task two:</u>

Accomplish the “180 ollie” maneuver in skate mode (remind to think out loud).

Steps:

1. Perform the first level
2. In the second level perform “180 Ollie” maneuver

How easy or difficult it was to perform such maneuver (tick the appropriate grade):

Not completed	Hard to execute	Neither hard nor easy	Easy to execute	Very easy to execute
1	2	3	4	5

Usability analyzer will ask you for some comments. You can only continue after those have been asked.

Task three:

Playing in Bmx mode go to pause menu and learn how to perform the "tailwhip" trick (remind to think out loud).

Steps:

1. Return to the main menu and choose BMX mode;
2. Start the play mode and enter pause menu;
3. In the pause menu find how to perform "tailwhip" trick.

If found, rate the usefulness of the Trickology list found (tick the appropriate grade):

Not useful				**Very useful**
1	2	3	4	5

Usability analyzer will ask you for some comments. You can only continue after those have been asked.

Task four:

Eliminate your saved game and start a new one choosing a character with a different sex than you have before (remind to think out aloud).

Usability analyzer will ask you for some comments. You can only continue after those have been asked.

Satisfaction

How do you rate the gameplay of the application:

Poor	Adequate	Satisfactory	Good	Very Good
1	2	3	4	5

How do you rate the design of the game application:

Poor	Adequate	Satisfactory	Good	Very Good
1	2	3	4	5

How do you rate the usefulness of the tutorials showed:

Poor	Adequate	Satisfactory	Good	Very Good
1	2	3	4	5

Usability analyzer will ask you for some comments. You can only continue after those have been asked.

Would you use this game application again? Would you recommend it to someone? Why?

If you could what would you improve in this game application?

I Find myself overall satisfied with this game application (tick your appropriate grade) :

Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
1	2	3	4	5

Thank you for your cooperation